Whirlpool Corporation
WOODRIDGE ENERGY STUDY & MONITORING PILOT

Project Report by

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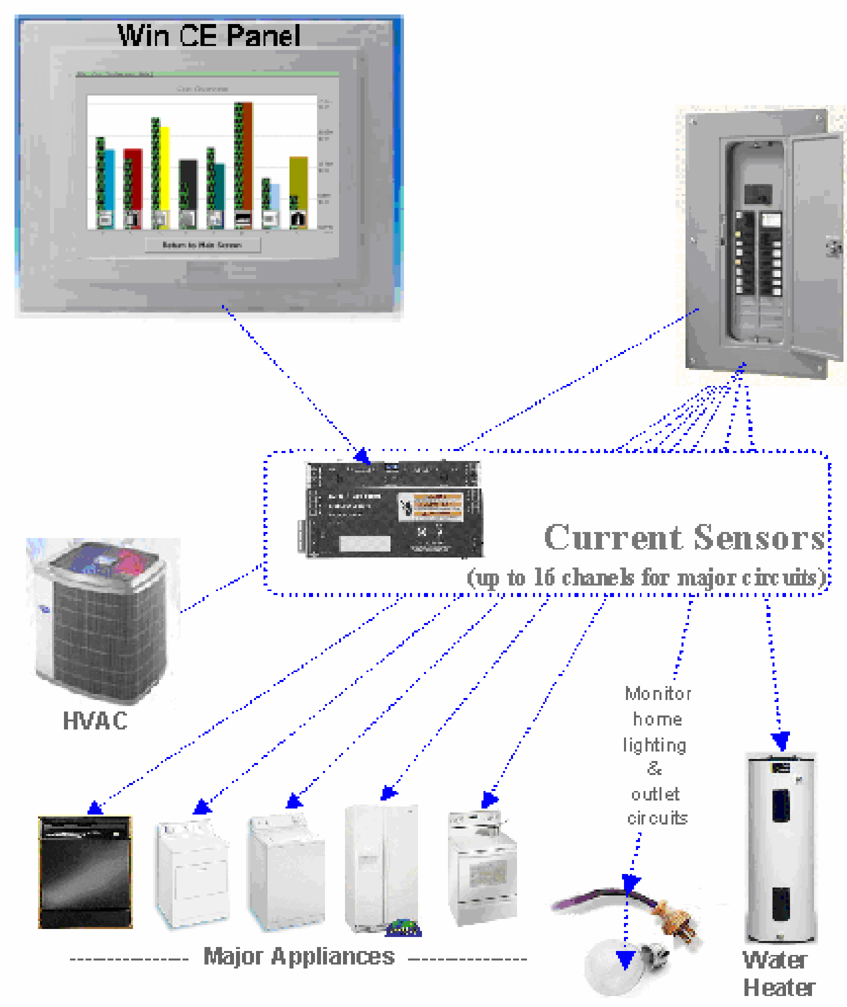
Energy Monitoring System



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Note: When printing this report, use of a color printer is highly recommended.

Project summary:

Whirlpool Corporation initiated a residential energy pilot in a local community in Benton Harbor Michigan. The program, which concluded the first quarter of 2006, helped consumers save money by shifting their energy consumption to a lower evening rate. Each home was equipped with 3 appliances that, once loaded with laundry or dishes, will automatically start when the electric rate drops to the evening off-peak rate. In addition, each home was outfit with a color touch-screen monitor that displayed real-time and historical data on each measured circuit in the home. The combination of the energy visibility technology and the pilot appliances showed a positive benefit for the consumers living in the test homes. Detailed data downloaded from the consumer test systems has been graphed for data mining and providing data that can be compared with national and regional averages.

Background:

Whirlpool Corporation (see www.WhirlpoolCorp.com.) is the world's leading manufacturer and marketer of major home appliances. Whirlpool has had significant energy conservation achievements since its early beginnings when Louis, Frederick and Emory Upton created the Upton Machine Company in 1911 to produce electric, motor-driven wringer washers. With more than 60 manufacturing and technology research centers around the world, Whirlpool Corporation markets Whirlpool, Maytag, KitchenAid, Jenn-Air, Amana, Brastemp, Bauknecht, and other major brand names to consumers in nearly every country around the world.

In 2003, Whirlpool initiated an energy conservation innovation project with a consumer study covering energy usage visibility, monitoring, and appliance load peak shifting. The "Woodridge" Project, named for the Michigan housing community where it was initiated, was an opportunity for Whirlpool to take the leadership role in the study of several key concepts in consumer energy use and lifestyle choices relative to energy consumption in general.

Why did Whirlpool conduct this program?

In the future, we believe energy consumption will be managed in a cooperative manner. The technology in these future systems will allow consumers to manage energy consumption in a way that reduces the need for additional power generating plants. Consumers who understand their energy consumption patterns will be able to both contribute to these efforts as well as enjoy a substantial savings in their energy costs. While these savings may not always lower current residential energy costs, they can help avoid the rising costs experienced by consumers in certain geographic areas.

The energy industry often includes residential appliances in energy reports. However, managing energy in complex appliance processes is difficult or impossible to do external to the appliance itself. Whirlpool invested in this research to understand future energy trends, solutions, and technology to further the consumers' ability to manage energy helping to shape the future. As a consumer-oriented company, Whirlpool wants to be prepared to assist consumers in managing their energy needs in a non-intrusive manner. This pilot program is helping to understand the issues surrounding home appliance energy management by placing prototype appliances into consumer homes. The data will also guide future development of technology supporting the energy managed home.

Installed Whirlpool energy monitor touch-screen

Primary motivators for the study

The primary motivators for the Woodridge study covered the following areas of interest:

1. Understand consumer reaction to TOU (time-of-use) electric tariff. TOU electric rates allow a different tariff (charge or cost) for electricity consumed at different times of the day. Thus the name "time-of-use", or TOU for short. In this case, the cost per kilowatt hour is lower during evening and weekend hours.
2. Understand whether consumers will accept and utilize appliances that have built-in accommodations for TOU.
3. Learn how detailed real-time energy consumption visibility will impact consumer's attitudes and habits surrounding energy usage.
4. Understand when consumers use their appliances and household energy in general.

1 - Understanding consumer reaction to time-of-use (TOU) billing

Will consumers accept TOU, or will they perceive it as an objectionable requirement forced upon them by their utility company? Although participation in the Woodridge pilot was voluntary, participants had to agree to enroll in the local TOU tariff. The Michigan TOU Tariff (AEP Tariff 030) is a fixed peak/off-peak rate. Peak is from 7:00 a.m. to 9:00p.m.

As of the writing of this document the TOU tariff can be found on page 93 of the document obtainable at the link below.

https://www.indianamichiganpower.com/global/utilities/tariffs/Michigan/MISTD5-15-06.pdf

(This file is updated occasionally. If the link fails, start at the root (indianamichiganpower.com) or aepcustomer.com and search from there.)

In brief, the tariff breaks out as:

	Generation	OATT Transmission	Retail Transmission	Distribution	Total
Service Chg ($)				7.40	**7.40**
On-Peak ¢ per kWh	4.892	0.777	0.095	2.159	**7.923**
Off-Peak ¢ per kWh	1.869	0	0	0	**1.869**

For this tariff, the on-peak billing period is defined as 7 a.m. to 9 p.m., local time, for weekdays, Monday through Friday. The off-peak billing period is defined as 9 p.m. to 7 a.m. for all weekdays, all hours of the day on Saturdays and Sundays, and the legal holidays of New Year's Day, Memorial Day, Independence Day, Labor Day, Thanksgiving Day, and Christmas Day. In addition to the above, various commission-approved riders contribute to the residential monthly charges. For the purpose of this experiment, we deal with only the on-peak rate of 7.923 cents per kWh and the off-peak rate of 1.869 cents. For the comparison with a fixed rate, we used an average fixed rate of 5.8 cents per kWh for this region. The fixed rate is AEP (Indiana Michigan Power Company) tariff 016 described on page 89 of the same online document referenced in the link above.

Unlike many utility programs rolled out in mass, Woodridge consumers had the opportunity to hear about utility company peak issues and the reasons why TOU is a reasonable solution during a one-on-one customer session. This educational aspect allowed prospective participants to ask questions and become comfortable about their choice to participate and enroll in the TOU tariff. The purpose of the study was not intended to, in any way, evaluate the method by which consumers become educated regarding TOU. The focus was their response to TOU and the technology that helps them take advantage of the TOU tariff. Once the consumer is fully educated about TOU, we wanted to understand if and how they would adjust their lifestyles.

2 - Appliances with TOU features

Once consumers are educated regarding TOU motivation and rate structure, we needed to know whether having an appliance that automatically helps them shift energy to off-peak would be considered a valuable feature. As detailed later in this document, the consumers were provided a dishwasher, clothes washer, and clothes dryer with an off-peak DSM (demand-side managed) feature. DSM is a concept of managing the amount of electricity used at a particular time. This managing of the demand, is an alternative to building additional power plants.

3 - Energy visibility

If the consumer can see detailed energy consumption information in both real time and historically, how will this affect their energy consumption habits?

4 - Consumer appliance usage

Several questions come into play regarding appliance usage. What is the actual amount of energy consumed by current model appliances? Although the selected appliance models are not the most efficient of each respective type, EnergyStar-rated appliances were selected where applicable. When are people using their appliances? What other data mining is possible utilizing sub-metered residential energy consumption data?

Statistical notes

Control group

A control group of the same appliances as the DSM set would have provided a more accurate comparison, as this program only monitored homes with the Whirlpool DSM test appliances. However, for a statistically significant comparison with a control group, many more households would have needed to be involved both in the control group and the DSM group. The cost of such a complete study is more than the sponsor wanted to bear. Therefore the purpose of this study and report is to clearly show the findings and maximize what we can learn from a small group of test homes.

For the purpose of control group comparison, we refer you to the **ELCAP**[1] study and the **Parker**[2] study each of which details sub-metered residential electric use. You will find these reports useful in comparing our data with homes that were measured without an attempt to change consumer behavior.

Lifestyle & demographics

While a considerably larger study is needed to accurately portray lifestyle and demographics, we were amazed at the differences in electric usage logged by the primary four participants. Even with a larger than desirable error factor (which we did not attempt to compute) due to the small study size, we strongly feel that the desired change in consumer behavior demonstrated in this study is valid. Evidenced by both the gathered data and consumer interviews, there is ability to influence consumer behavior via the consumer education and technologies provided.

There is one interesting and significant element in the Woodridge study that highlights the appliance energy usage. The 4 homes utilized for the majority of the home comparison data (unless otherwise noted) have the following appliances models in common:

Washer, Dryer, Dishwasher, Microwave / Hood Combo, Range

In effect, we eliminate all factors related to the age, brand, and model of the core appliances in these four homes. This helps identify the differences in consumption on these electric circuits as being the result of consumer behavior and not differences in the appliances themselves.

New homes were selected for a variety of reasons beyond the scope of this discussion. With varying completion and closing dates, the start and end dates of the study were subject to more flex than envisioned. The final data from the four main homes all overlapped the calendar year 2005. Therefore, the graphed data included in this report reflects January - December of 2005.

Consumers & expectations

Consumer response to energy pricing schedules to reduce electric demand during peak electricity generation periods was one of several key factors. Seeking to understand the impact of appliance design and consumer acceptance, Whirlpool designed the Woodridge pilot to observe several aspects of consumer motivated energy management.

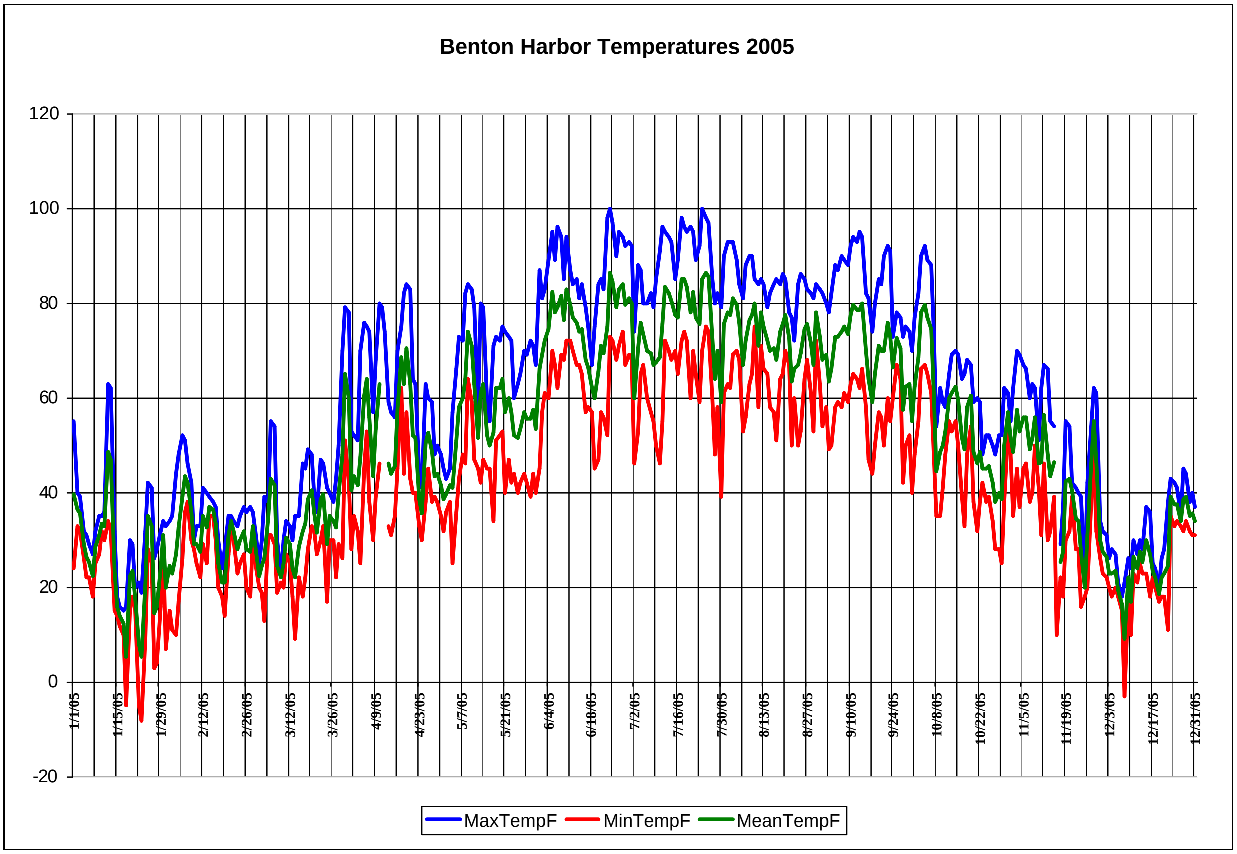
Location and Weather History for the Woodridge pilot

For cost and convenience, the study was conducted near the Whirlpool world headquarters in Benton Harbor, Michigan. Those interested in additional weather details can easily seek further information from a variety of online sources. In brief, the climate is affected to a significant degree by the proximity to Lake Michigan. The homes in the Woodridge community are less than a mile from the shores of Lake Michigan. This tends to result in some warmer temperatures in the winter and cooler temperatures in the summer as compared with other regions within 100 miles of Benton Harbor.

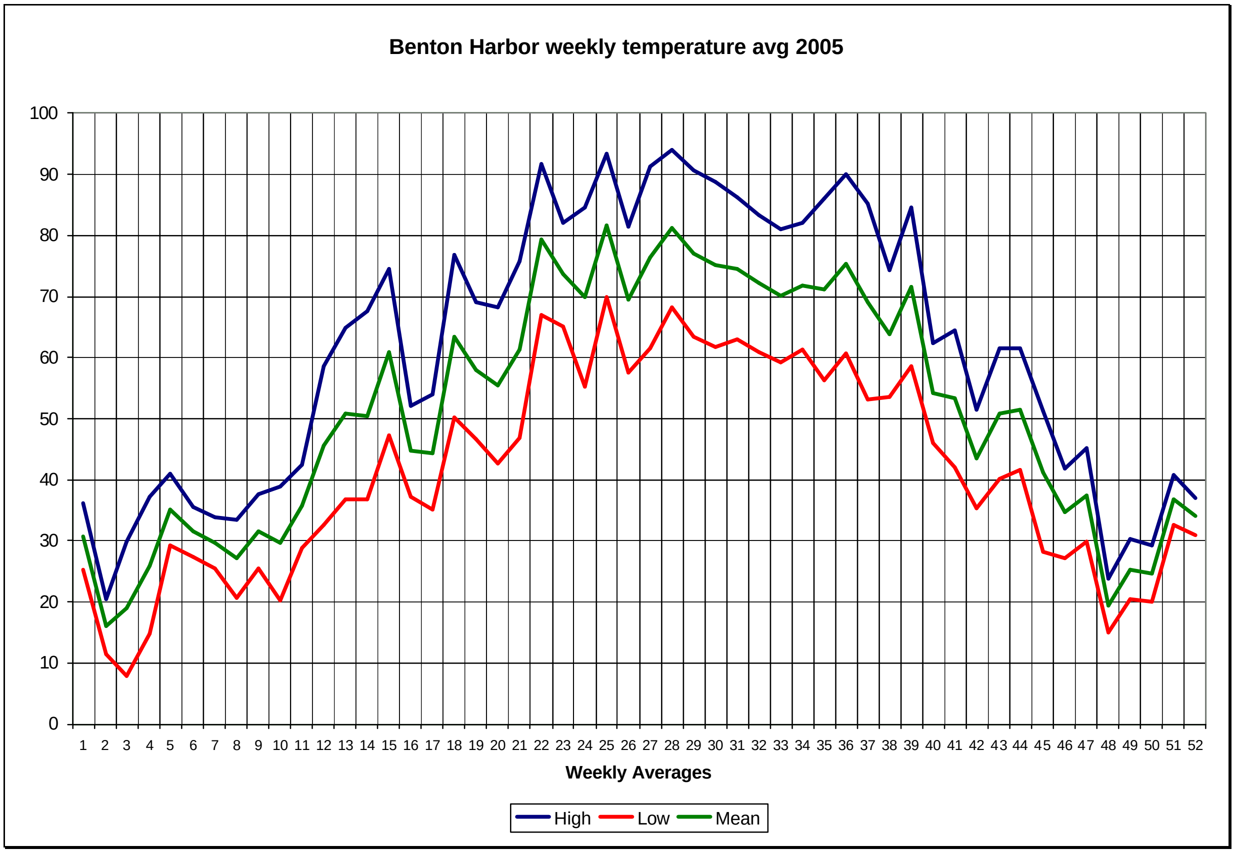

Woodridge community
Muskegon
Milwaukee
Lake Michigan
Fruitport
Waukesha
Holland
Dorr
Kenosha
Antioch
Waukegan
Highland Park
Palatine
Chicago
Dekalb
Cassopolis
Aurora
South Bend
Gary
Joliet
Nappanee
Frankfort
Valparaiso
Tri-Lakes

Benton Harbor weather history for 2005

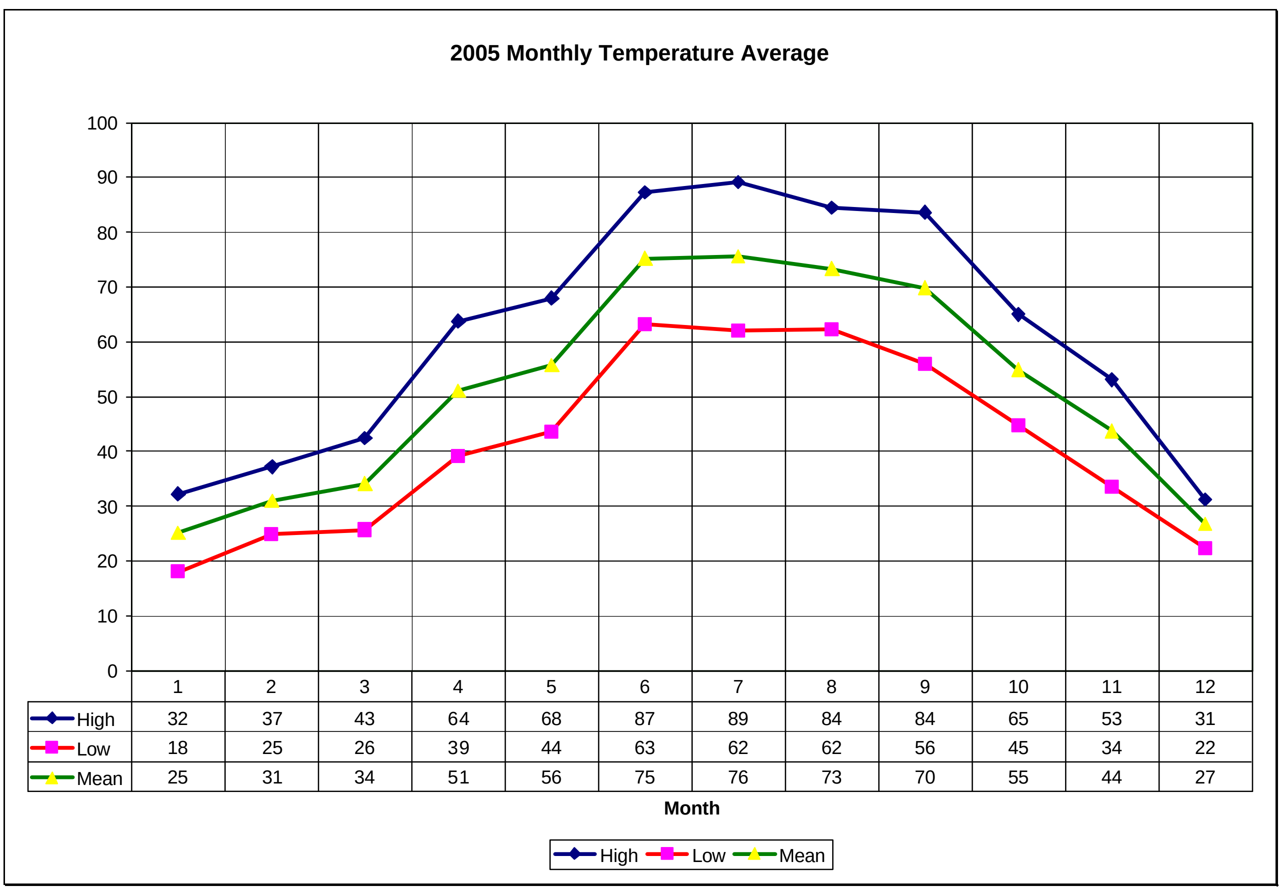
The temperatures were measured at Ross Field in Benton Harbor, Michigan. Ross Field is located within approximately one mile of the Woodridge community of homes. Graphs 1-3 below show the weather pattern during the year 2005 by daily, weekly, and monthly averages.



Graph 1



Graph 2



	1	2	3	4	5	6	7	8	9	10	11	12
High	32	37	43	64	68	87	89	84	84	65	53	31
Low	18	25	26	39	44	63	62	62	56	45	34	22
Mean	25	31	34	51	56	75	76	73	70	55	44	27

Graph 3

Consumer lifestyle impact:

Consumers have, over years of unrestrained energy consumption, grown accustomed to having energy when they desire it. Whirlpool Corporation conducted two consumer focus group sessions. One was conducted in the North suburbs of Chicago, Illinois. A second was held in San Jose, California. The moderator guided a discussion on energy management followed by sample screens of an energy management and consumption visibility tool.

"Headlines" from consumer focus group sessions:

- Primary motivations for consumers to save energy:
  - to "save money" (CA/IL)
  - to "do my part to protect the environment" (CA/IL)
  - to avoid blackouts or the threat of blackouts (CA)
- Energy is an entitlement - “I shouldn’t have to worry about it” (general)
- “We feel trapped into high energy costs.” (CA)
- Energy management may require a lifestyle change since consumers have to interact with appliance products.
  - Resistance to lifestyle changes (IL)
  - Already made energy-related lifestyle changes (CA)
- “We must decide how we want to spend our energy allotment today?” (CA)
- Until it hits their pocketbook significantly (> $40 / month), many consumers are not willing to change their lifestyle to manage energy.
- Being able to see and pinpoint areas of home electricity use was a welcome idea viewed as a consumer advantage. Response to the concept of a home energy monitoring tool:
  - “Would be useful for me to see energy use by device / room / etc.”
  - “A convenient consumer decision making tool, rather than forced compliance”
- “We want to save energy where it makes sense but don’t let it control our lives.”

One key that seemed to be apparent is that consumers don't want to think about energy or be forced to change their lifestyles. Consumers expect a comfortable solution with minimal inconvenience. Whoever is the bearer of news to the contrary is subject to consumer disdain and ridicule. Note that a disgruntled residential utility customer is usually still a utility customer. However, a disgruntled appliance customer has a more convenient choice to become an ex-customer. Therefore an appliance manufacturer has a lot at stake when introducing energy management concepts.

"Show me the energy..."

In the course of the focus group discussions, the participants realized that managing energy used by their appliances might imply a lifestyle change because of the potential impact on <u>when</u> they should use appliances. With this realization in mind, the consumers gave <u>energy usage visibility</u> a higher priority than <u>automation</u> of energy management. Consumers liked the idea of being able to see their home energy consumption broken down by circuit or appliance. This theme of <u>education & visibility</u> was a motivator for the energy monitoring system Whirlpool developed for the pilot discussed in this report.

Participant selection:

Note that data for detailed energy consumption by circuit is difficult and expensive to obtain. A data cable had to be installed along with sensors on the mains and the breakers in each home. These items are easier to install during construction. For ease of selection and ability to address the installation issues, new homes were selected. Although this was arguably not the best choice since there was no pre-existing energy consumption data. For the purpose of energy visibility impact from the consumer attitudes and expectations perspective, this was not deemed a significant issue for Whirlpool. Data on appliances and other home circuits were considered adequate for the goals of the project.

Selection requirements and notations:

- The home had to be owner occupied
- Size was not a selection criterion other than needing to know the square footage of the home.
- Heating source not specified. However it was deemed desirable to represent several different types of HVAC equipment in the selected homes.
- Must have children in the home (one or more).
- Owner willing to sign up for the local residential TOU electric tariff.
- Owner agrees to up to 4 surveys or interviews.
- Accept and utilize the DSM appliances (washer/dryer/dishwasher) for the duration of the study.
- Allow Whirlpool to install the energy monitor touchscreen and sub-metering equipment.
- At the end of the study participants received, at no cost, replacements for the three test TOU appliances utilized during the pilot.

Information on the pilot homes:

There were a total of seven homes involved in the energy monitoring pilot. Four of these were in the Woodridge subdivision and considered the core of the pilot. As with any such undertaking, circumstances can change that affect the data. For example, one occupant family vacated the home after several months leaving us with less than a full year's data on that home. Due to the failure of some technical components, there were several minor gaps in data.

Four of the homes contained the special pilot DSM appliances (described on page 14). As a result, **the graphs represent the data from these four homes** (unless indicated otherwise).

Specifics about the DSM homes:

Home #1: Traditional forced air gas heat and a gas water heater. Two story home occupied by family with 4 children.

Home #2: Energy efficient design. Insulated concrete walls heated via warm water circulated through the floor. Single story home occupied by family with two children.

Home #3: Traditional forced air gas heat and a gas water heater. Single story home occupied by family with 2 children.

Home #4: Traditional forced air gas heat and a gas water heater. Single story home occupied by family with 1 child (plus a second baby that arrived on the scene during the pilot).

The Woodridge technology

The Woodridge study consisted of three primary pieces of technology:

1) Stand-Alone Time-of-Use (TOU) appliances (Washer/Dryer/Dishwasher)
2) The Whirlpool Energy Monitor where consumers view energy consumption in real-time and historically via a 12" color touch-screen.
3) Data logging where energy consumption is logged for each hour of the day for each measured circuit and the whole home. This data was accessible by the consumer as well as downloaded for further study.

Additionally, consumers were surveyed for energy learning and reactions to having the energy visibility in their home. This survey uncovered consumer insights on how the addition of energy usage visibility impacted their cost and lifestyle. See page 89 for a survey summary.

The program initiated with the first installation in the fall of 2003 and the last home installation in December 2004. A new home completion delayed the closing and installation on the last test home. The pilot program and data gathering continued through March of 2006.

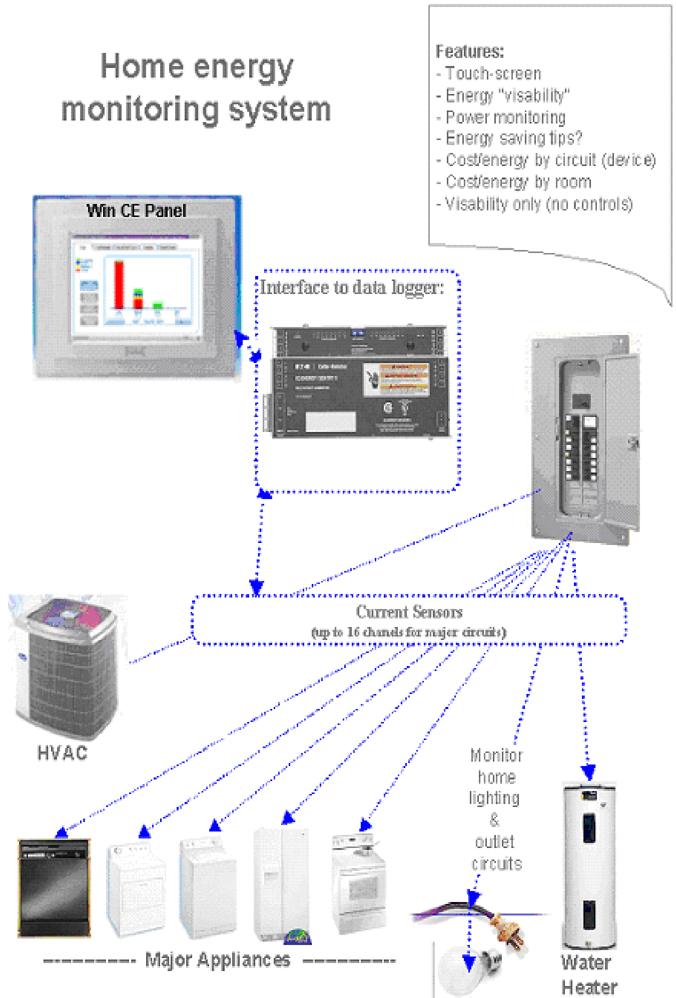
Stand-alone time-of-use "DSM" appliances (washer/dryer/dishwasher)

Whirlpool developed pilot appliances that have the daily Time-of-Use segments updated into the control. We refer to these as the DSM (Demand Side Managed) appliances. The appliance controls contain red and green lights and a delayed start button. Red indicates peak time and the corresponding higher electric rate while green represents off-peak time. The consumer has the option of starting the appliance now, or, pressing the delay button to have the appliance automatically start at a time then TOU rates are lower. This interface is quite easy for the consumer to understand.

As shown in the graphic below, the control panel lets the consumer conveniently delay operation of their appliance until the energy prices are lower (off-peak rate). To delay until off-peak, the consumer can press a button and another LED illuminates to let them know that this appliance will start at a later time.

Picture 1

The Whirlpool Energy Monitor



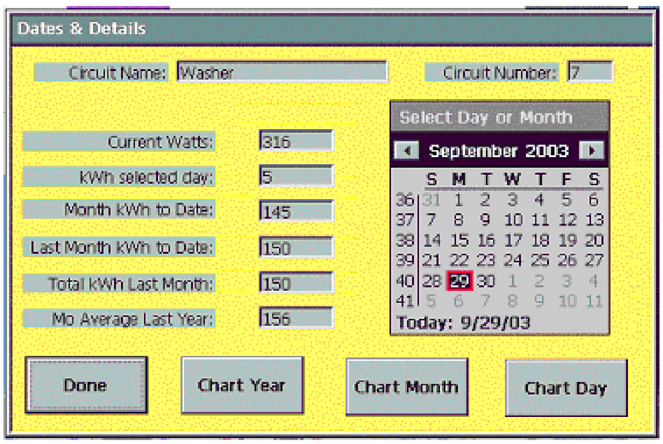
Picture 2

Whirlpool Corporation designed and maintained the energy monitoring system in residential homes in Benton Harbor for several years (2004 - 2006). The technology entails a comprehensive energy use reporting and tracking screen utilizing sub-metering devices and a 12-inch color touch-screen monitor. The system (see the diagram in Picture 2 above) gives consumers a visual display of current and past energy consumption. The ability to see and manage where energy dollars are consumed allows consumers to implement their own form of manual energy conservation. Knowing the monthly cost of each appliance provides detail to enable smart energy decisions as shown in several sample screens below.

One of the program requirements was to have a certain list of individual circuits (refrigerator, range, microwave, etc) to make the submetering effective. But when installing the sub-metering technology it quickly become apparent that each home and each residential electrician configures the the rest of the circuits uniquely. While one home may have several bedrooms combined onto a single circuit, another home combined the sockets in two bedrooms with part of the living room. While every home had a computer, the computers were not on a separate circuit. Each home located the computer in a different room. This included the basement, the kitchen, bedroom, and family room. Several homes had a finished basement while others did not. Several homes had a separate freezer on one of the plug load circuits.

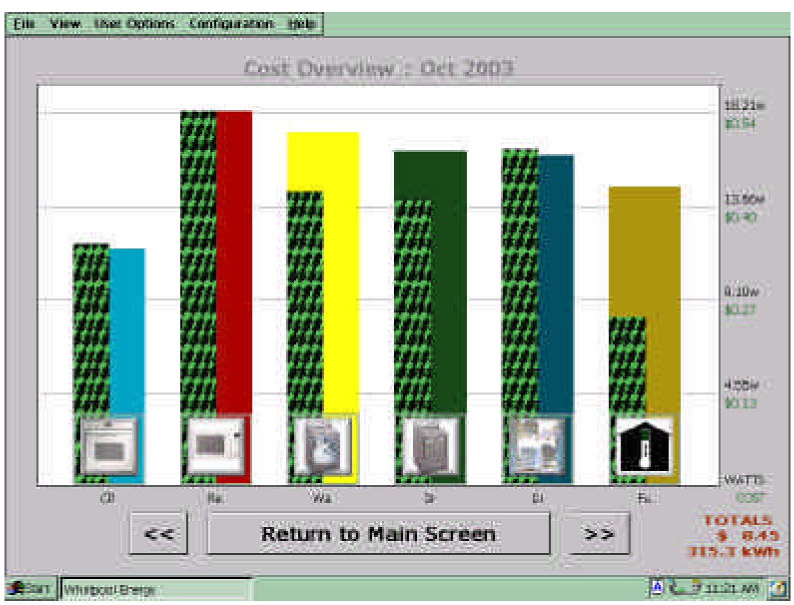
The monitoring system and touch-screen consisted of 16-channel submetering. Of the 16 channels, 2 were used on the mains while the other 14 were attached to individual circuits. (See additional details in the appendix starting on page 96). On the screen the customer sees up to 15 channels / bar-graphs concurrently (although they can select to monitor only select channels on screen at their option). Fourteen of the channels are specifically measured via current sensors in their electric panel. The "other" channel is a virtual channel determined by subtracting the sum of the 14 measured circuits from the sum of the mains. In this way, everything consuming energy in the home is either represented on an individual channel or as a component of the "other" channel.

It became apparent that comparing homes would have to be done mostly on the circuits common to all homes and the "other" loads combined. Each home has a separate pie chart of its load breakdown (starting on page 75) that includes all 15 displayed circuits. However, some are unique to the homes that had, for example, a whirlpool tub, HEPA filter system, outside lighting, and different plug configurations etcetera that other homes did not have.



Picture 3

Consumers may select a calendar day, month, or year as shown in picture 3 above.

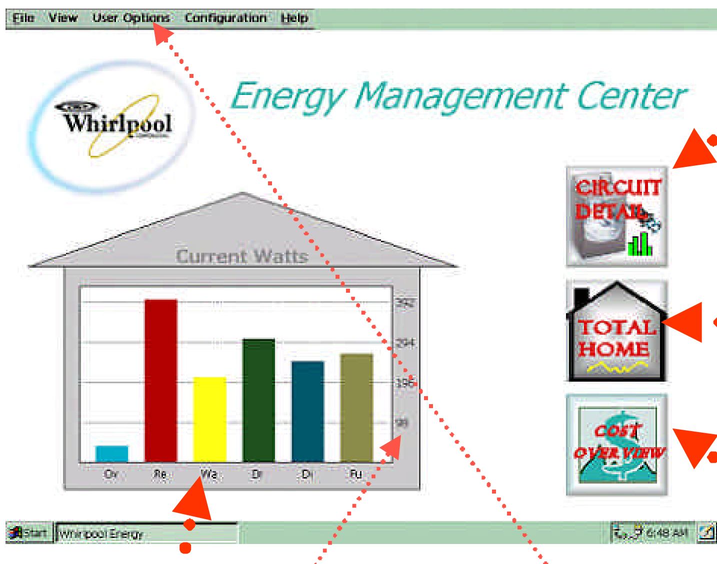


Picture 4

The example screen in picture 4 above both compares selected appliances, as well as showing the impact of the TOU (time-of-use) rate.

Data gathered from this pilot on both sub-metered consumption histories as well as in consumer feedback interviews are documented in this report. This helps us understand the focus group feedback regarding the desire to visualize energy consumption as a way to manage personal energy consumption related cost.

Current Watts house-graph



Show energy consumption history details graph, from which you may further explore the energy consumption history of each circuit.

Show energy consumption history details for the entire home. From here you may further explore the energy consumption history of your home.

A quick shortcut to view the energy cost of each circuit.

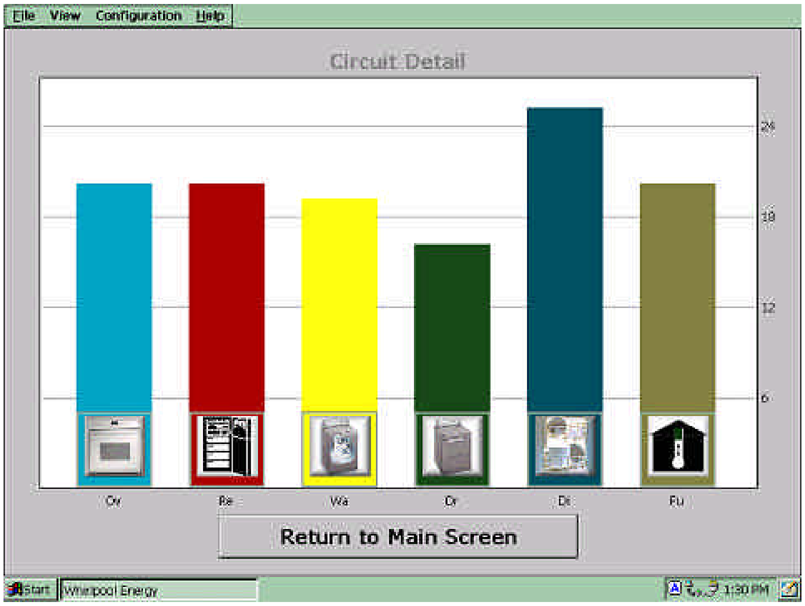
The graph on main screen indicates the actual power consumed by each monitored circuit. The bar graph values shown, in watts, are scaled so the top of the graph represents the largest amount of energy currently used. As the values change, you will see the scaled values on the right of the house graphic change to indicate the current scaled values. If a single circuit is consuming significantly more power than any of the other circuits, you will see that bar extend to the top of the graph while the others become very short in comparison.

Note: you can select which circuits are graphed via the **User Options** dropdown selection titled **Customer Circuit Configuration**.

Picture 5

The circuit detail screen

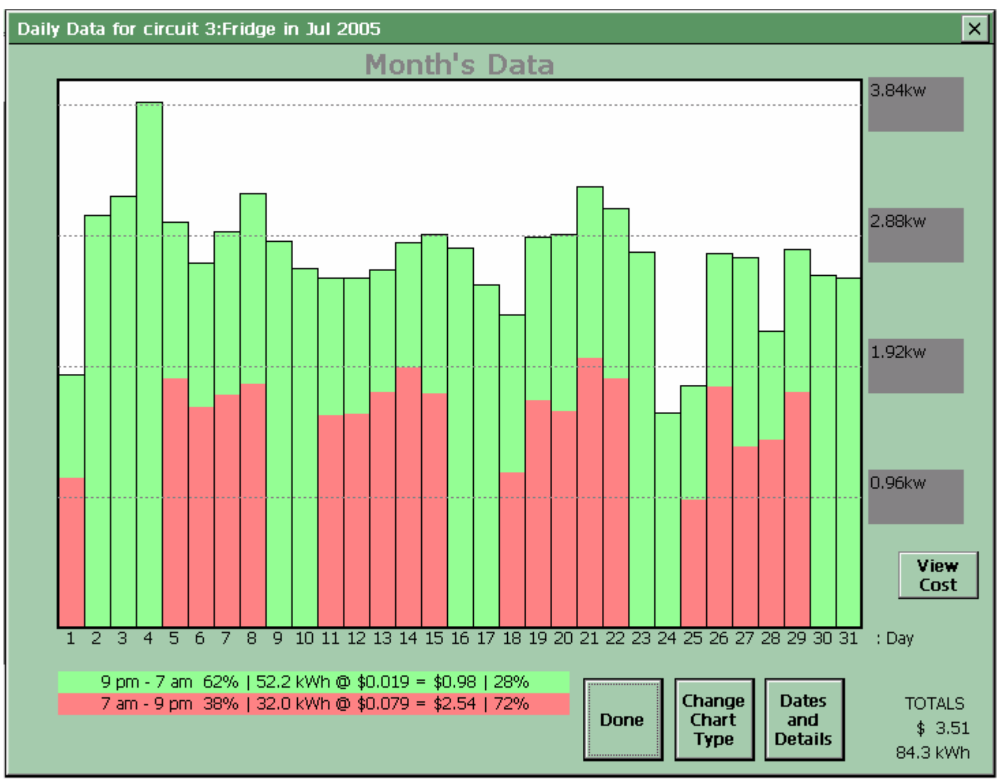
The **Circuit Detail** screen graphs the same data as the home screen but in a larger full-screen mode. Power being consumed at any given moment (1-7 seconds delay) is reflected in the bar graphs for each displayed circuit. The consumers can select which circuits they want to see on this screen, or all circuits can be displayed (This scales down the size of the icons and graphs).



Picture 6

Circuit Detail Screen

The consumer could display a day's data by hour for any given day. A month's data or a year's data can optionally be shown on the screen in a similar manner. In the example below (see Picture 7), the consumer can view the refrigerator energy consumption for one month. In this example, the refrigerator used 84.3 kWh for the month of July 2005 for a total cost of $3.51. The red indicates on-peak TOU rate while the green indicates off-peak cost charges.



Picture 7

One month's data for one circuit

Data analysis notes:

The load curve format is utilized for many of the graphs. This format shows the 24-hour day from left to right (x-axis). Since the time of day when energy usage goes up or down is of interest in energy studies, this format seemed appropriate. Cost or watts is at the left on the vertical axis (y-axis). The energy consumption graphed appears in watt hours and in some cases, as noted, kWh.

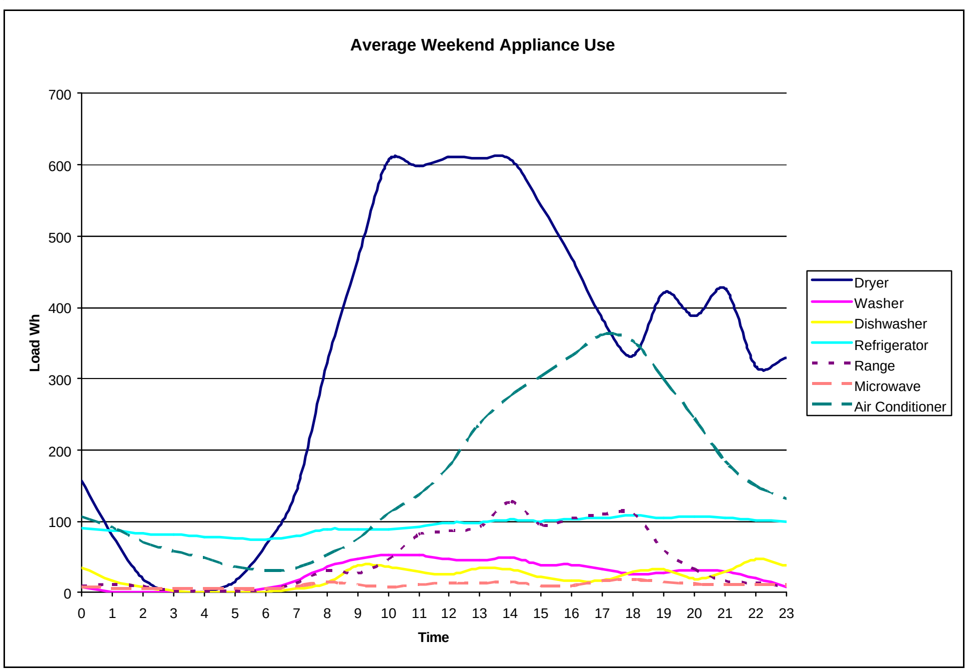
Note that the term "Appliance" in this report generally refers to consumer appliances such as clothes washer, clothes dryer, microwave, oven/stove, dishwasher, and air conditioner. "Appliance" does NOT include items such as TV, stereo, water heater, or miscellaneous plug loads. When the term DSM appliance is used, this refers to the Washer/Dryer/Dishwashers with the off-peak auto-start feature. Non-DSM refers to the other measured appliances in the homes such as refrigerator, stove/oven, microwave etc.

DSM and weekday vs. weekend data:

This set of graphs offers an evaluation of the DSM appliances (described on page 14) that help the consumer shift use to off-peak. We will also look at weekday use compared with weekend use which also plays a role in the off-peak shift.

Weekday vs. weekend data:

Weekday - weekend appliance comparison



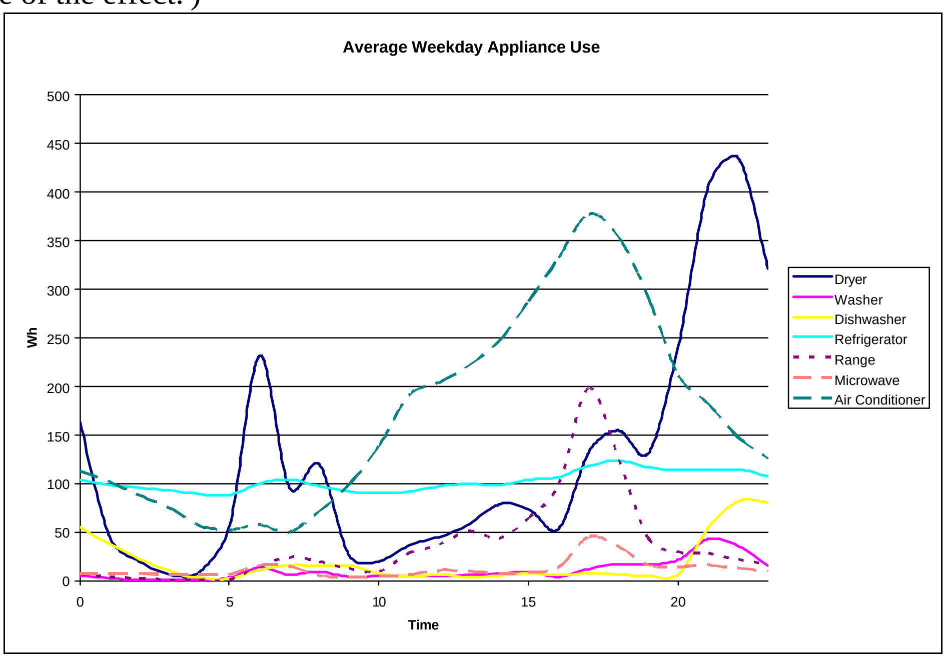
Graph 4

Graph 4 represents the weekends for the entire year averaged together showing an average weekend day. Here we see that the dryer uses, by far, the most energy on weekends. The y-axis on graphs 4 and 5 represents the monthly average amount of electricity used during each hour on a **weekend** (graph 4 above) and **weekday** (graph 5 below) shown in watt hours. Time period covered is Jan 2005 to Dec 2005.

The first thing you will notice on the graph above is the dryer. Since the weekend is off-peak, consumers appear to have moved much of their laundry tasks to the weekend. Another interesting observation is on the weekday graph below. The dryer shows a weekday spike before 7:00a.m. where some homes appear to have initiated laundry in the morning hours before the peak rate starts. In addition, after 9:00p.m. on weekdays, the DSM dryer makes quite a showing on the energy usage. Part of that spills over into the early morning hours as noted on the hours 0-1 at the left of both charts. The consumer interviews support the conclusion that consumers were using the DSM button on the dryers which correlates with the residential data shown.

Also observe the other individual DSM appliances (washer and dishwasher) where there is a significant observable difference. Most noticeable is the dishwasher in the weekday graph below where the consumers again pushed much of the dishwasher use to after 9:00 p.m.

The washer graph line tends to follow a similar curve as the dryer. What is not shown on the graph is the fact that there is an effect on the water heating that is driven by the use of the dishwasher and the clothes washer. Since the Michigan climate makes a gas water heater more attractive from a cost perspective (at least at this point in time), these new homes all opted for gas water heaters. Therefore the observable addition of hot water energy is not apparent in this particular graph. However later in the report, a graph appears from one of the other measured homes (where there were no DSM appliances) containing an electric water heater. (see page 87. where we show a washer graphed with the hot water attributable to the laundry use for a glimpse of the effect.)



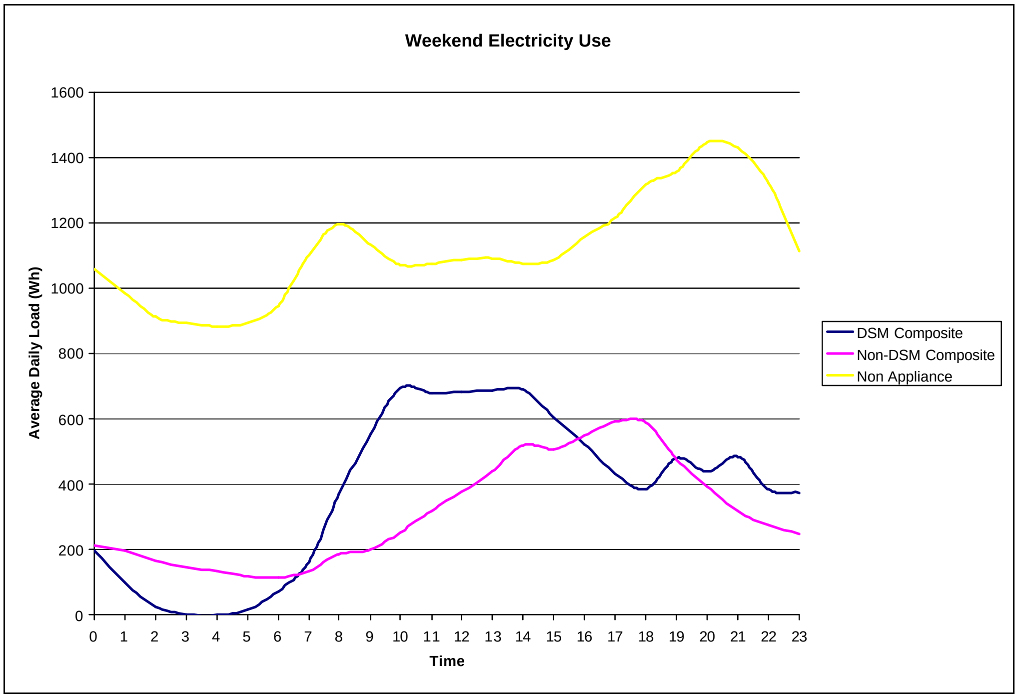
Graph 5

Summers are not usually extremely long and hot in Michigan but can vary widely. (See 2005 Benton Harbor weather information on page 10) Therefore, the dryers easily pushed Air

Conditioners in the test homes to second place for the averaged year. The AC also shows a load curve that rises later in the day than what may be observed in some other regions. This may be due in part to the location near Lake Michigan that leaves the daily minimum temperatures below the comfort zone during the evening hours causing the temperatures in these new properly insulated homes to rise slowly peaking the air conditioner use later in the afternoon.

DSM focused data:

Comparison of weekday vs. weekend for DSM, non-DSM appliances

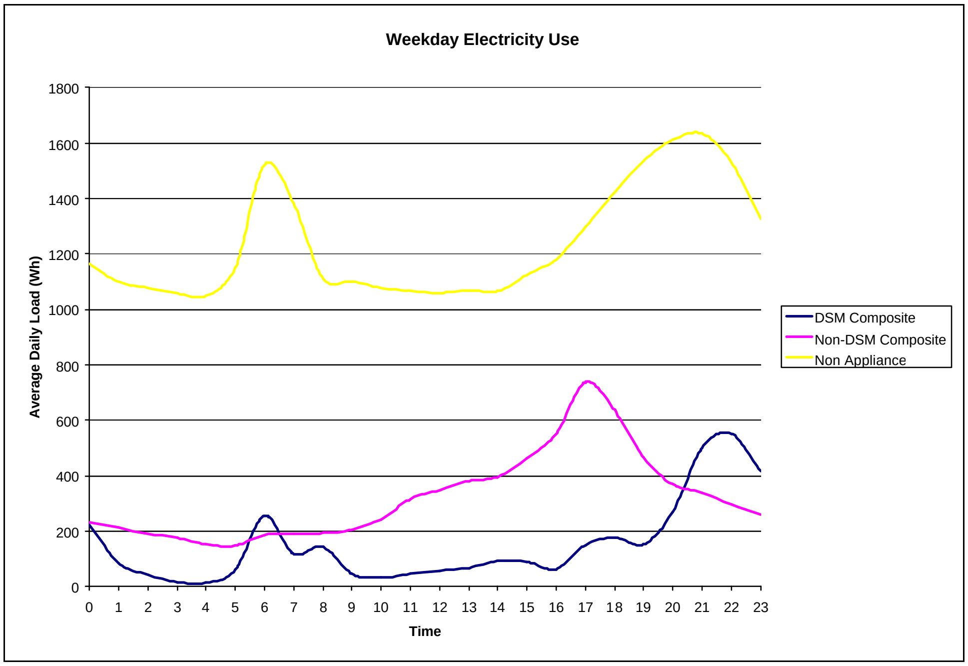


Graph 6

The y-axis represents the monthly average amount of electricity used during each hour on a **weekend** (graph 6 above) and **weekday** (graph 7 below) shown in watt hours. This compares DSM with other appliance averages over a time period from Jan 2005 to Dec 2005.

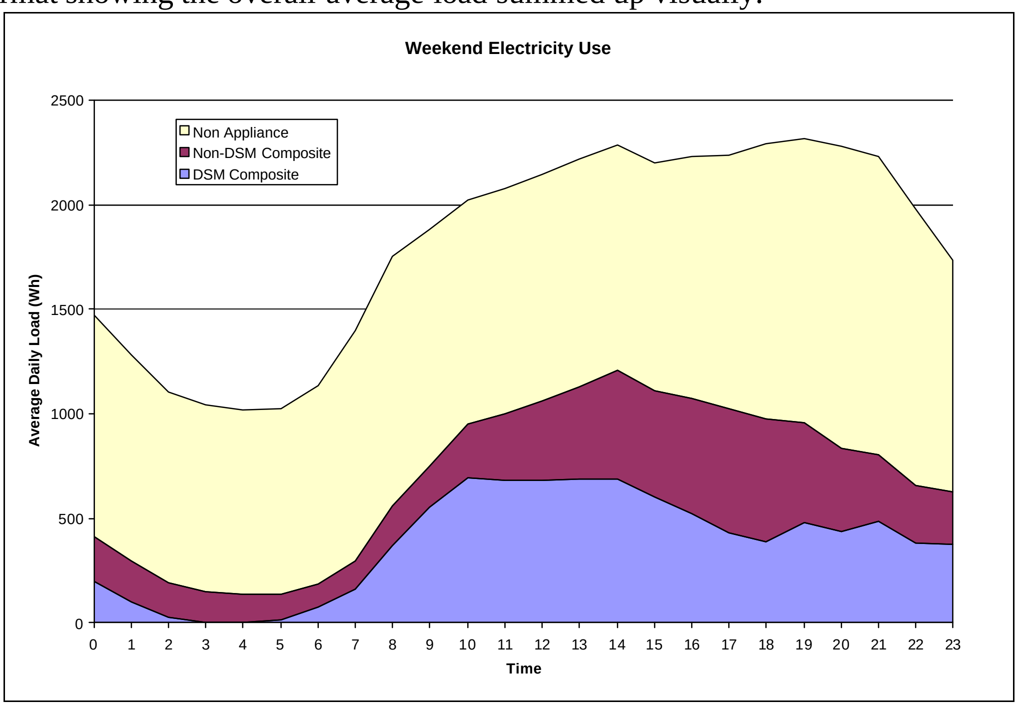
For the two DSM graphs (graphs 6 and 7), recall that the DSM composite line includes the washer, dryer, and dishwasher. Non-DSM composite includes the refrigerator, range, microwave, and air conditioner. Non-appliance is the total home load (measured at the mains) minus the load on the measured appliance circuits. In other words, ALL of the energy used in the home is represented in the sum of the lines on these graphs.

Of note are the early morning hump and the rise of the DSM composite line later in the evening in the weekday graph 7 below. In contrast, the DSM composite shows most of the weekend use during mid-day. In the graphs for the non-DSM loads, the lines show a similar trend for weekday and weekend usage.

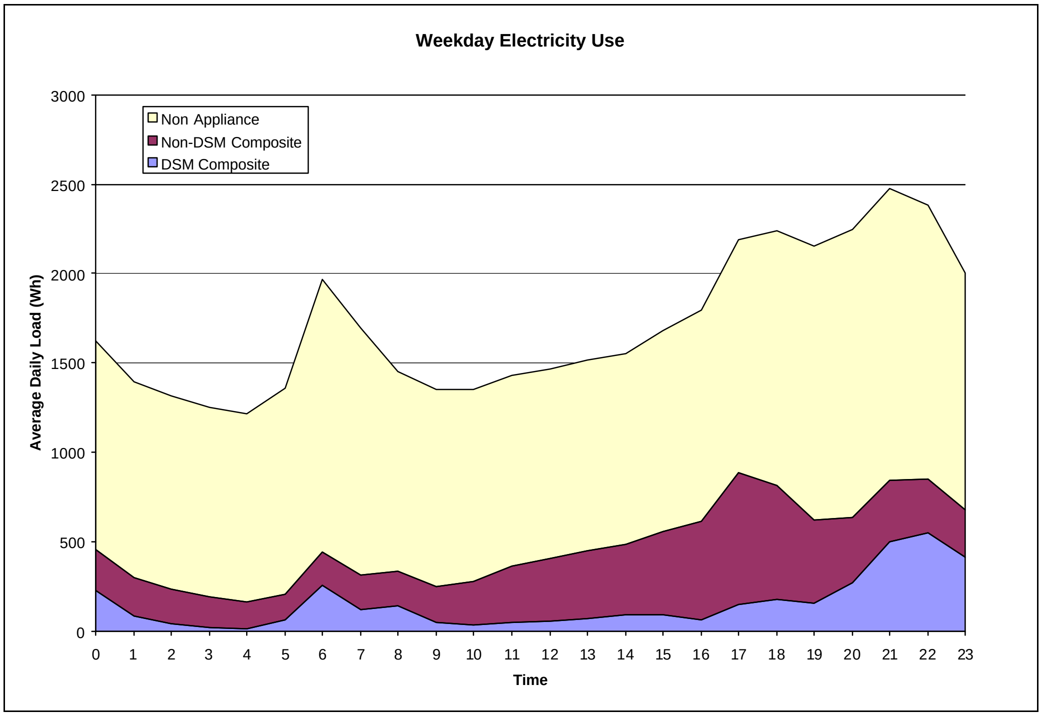


Graph 7

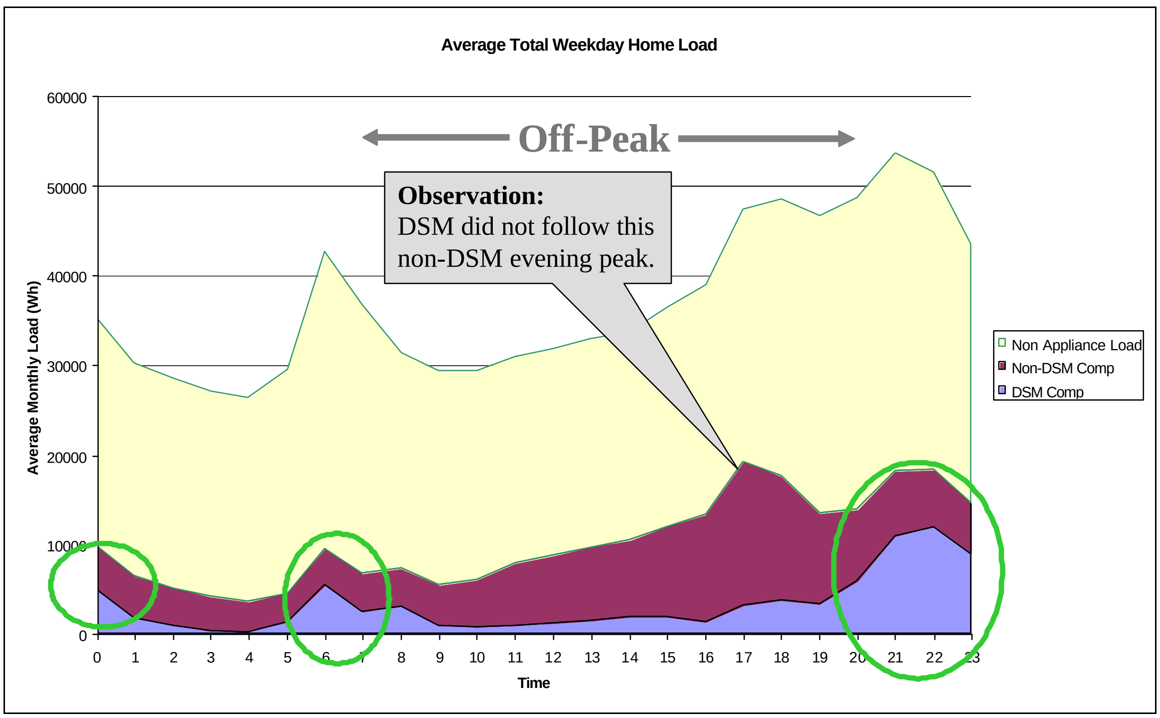
Graphs 8 and 9 below are the same data as graphs 6 and 7 above. They are shown in a stacked format showing the overall average load summed up visually.



Graph 8



Graph 9

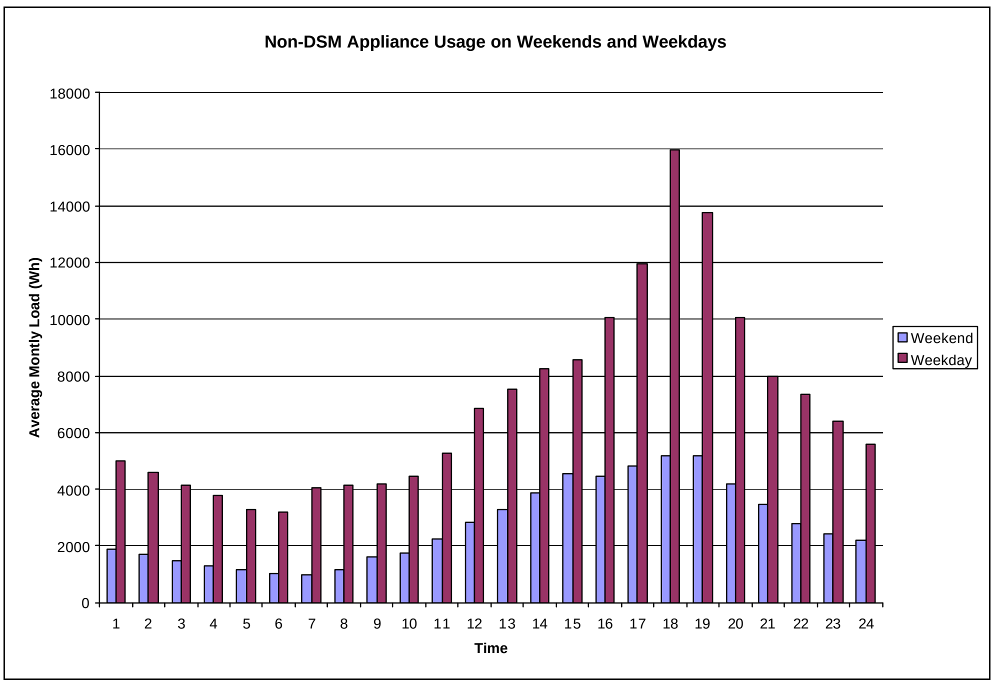


Graph 9-B

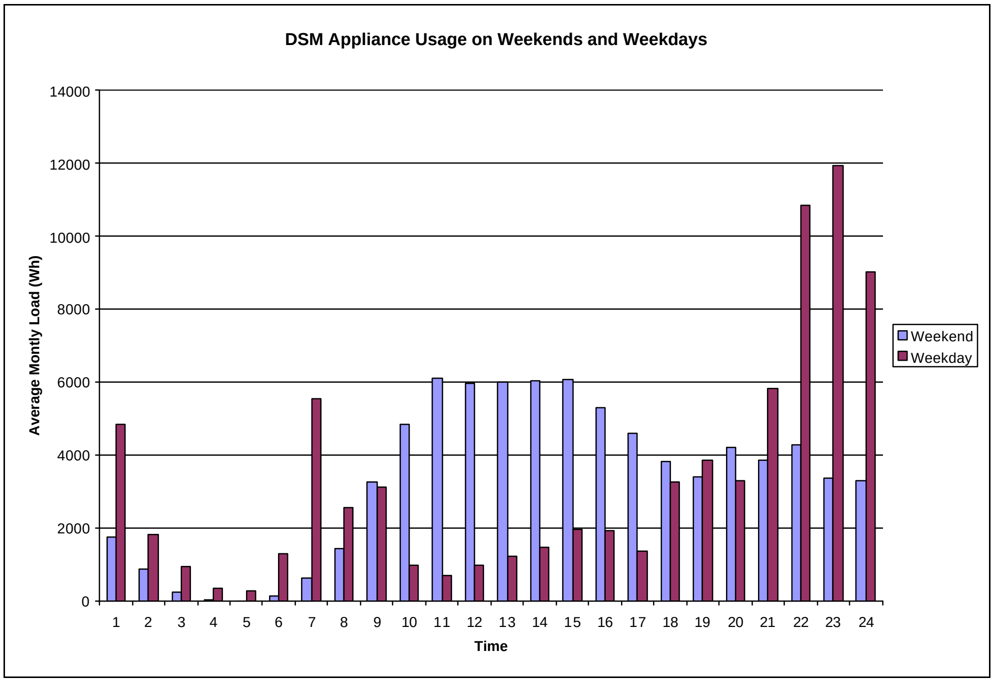
In the notations added to graph 9 (graph 9-B) we observe a typical evening peak at 5:00pm for the non-DSM appliances. Note that the DSM appliances invoke a peak that is shifted to 11:00pm and another small peak at 6:00am. This seems to infer that the consumers are using the delay function on the DSM appliances to shift the peak outside the normal curve.

The comparison of graphs 10 and 11 below illustrate the contrast between the weekend and weekday use of the DSM appliances vs. standard appliances. For the non-DSM appliances in graph 10 you see quite a smooth curve for both weekday and weekend. For weekdays it appears that the early evening is quite predictable as it peaks between 5 and 7 pm. The obvious implication is people arriving home and turning things on as well as cooking the evening meal, which drives a lot of use from stoves, cooktops, and ovens.

For the composite average of the three DSM appliances shown in Graph 11, we see evidence of the desired results. The mid day use shows a much different curve during weekdays. Non-DSM appliances follow the same general curve for both weekends and weekdays (Graph 10). The DSM appliances show a much different picture for weekdays compared with weekends. This seems to indicate a conscious effort to shift use to weekend off-peak time. In addition and also significant, is that weekday data shows a significant change to early morning and late evening off-peak usage for the DSM enabled products. This is observed in the red bars in graph 11.

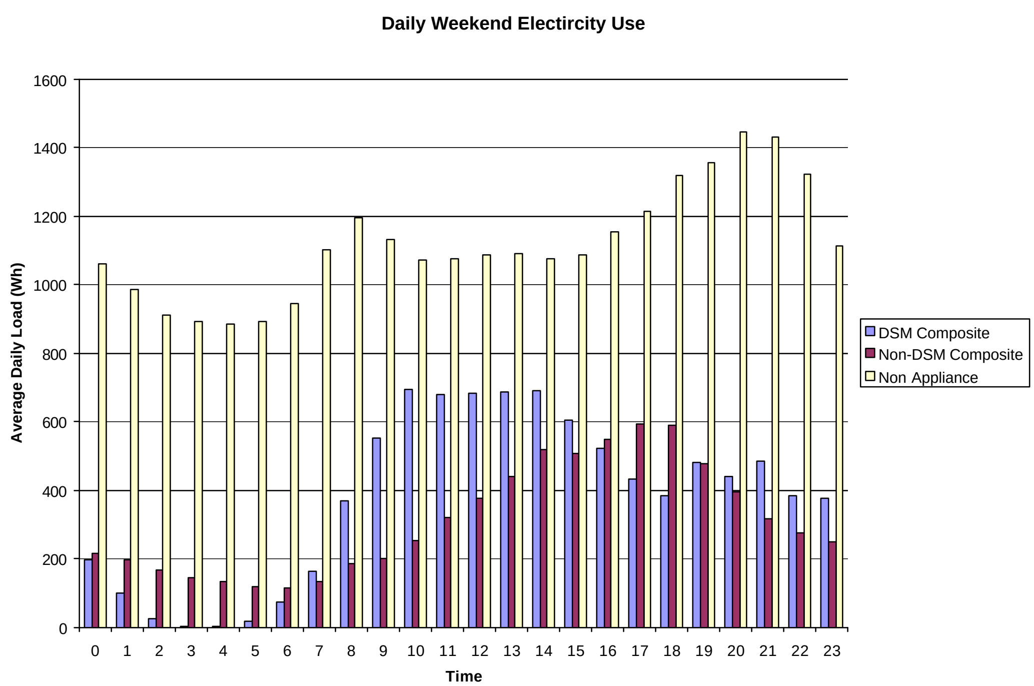


Graph 10

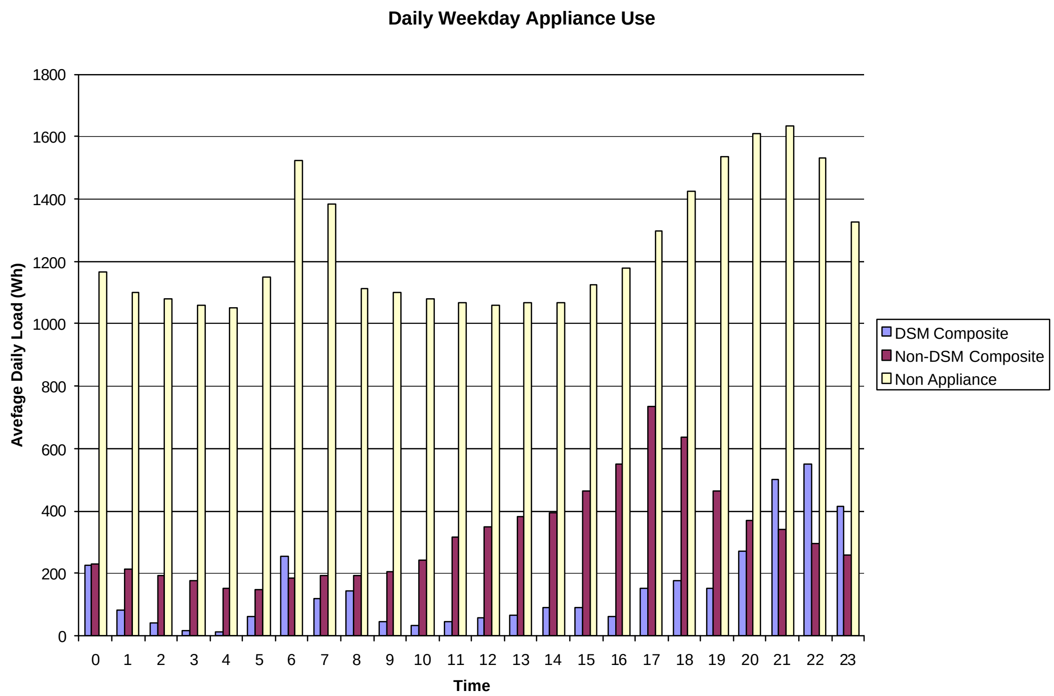


Graph 11

Graph 12 represents the average of all the electricity used in the homes by the DSM, non-DSM, and other categories. These represent that same data as in graphs 8 and 9 but shown in an un-stacked format. This provides an easier comparison of the actual values for each category timeslot.



Graph 12

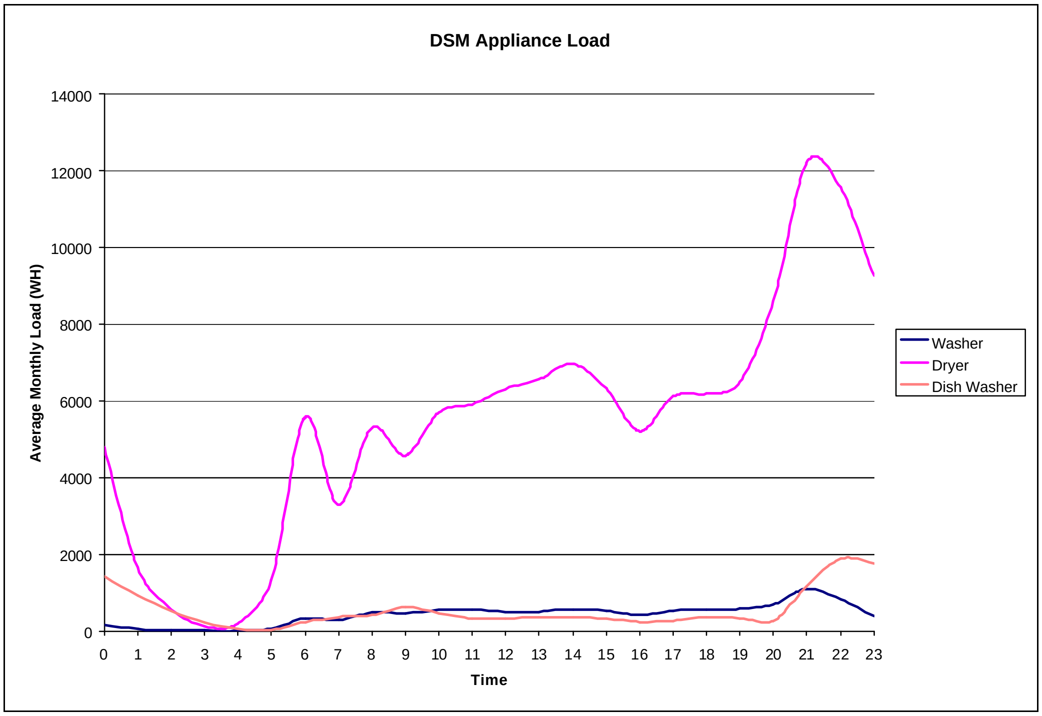


Graph 13

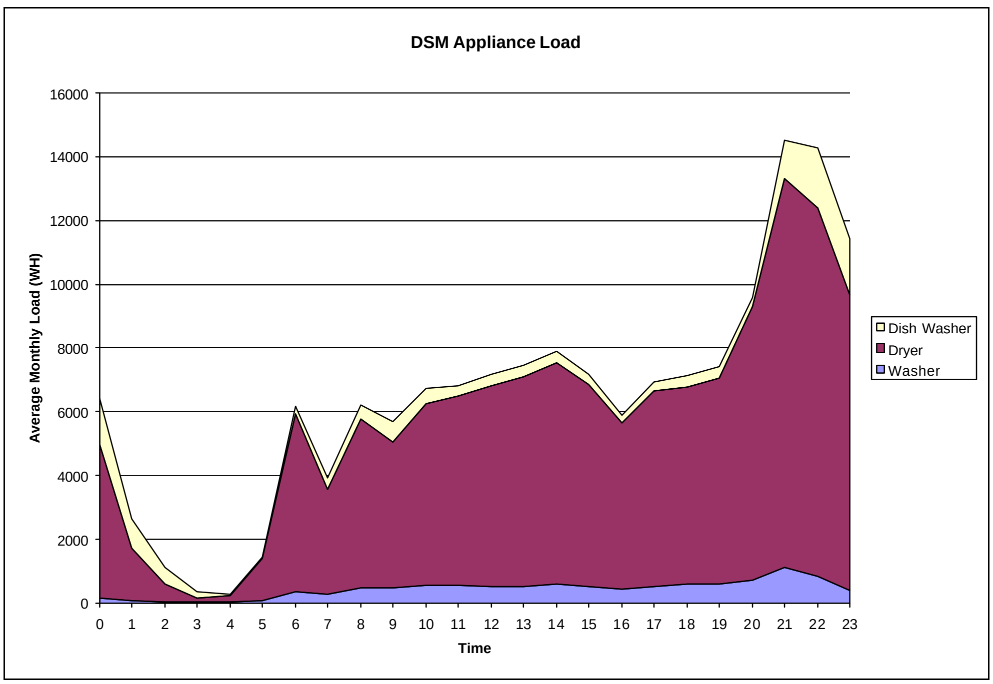
General load curves (Combined weekday & weekend) for DSM appliance comparison

Breakdown of the 3 appliance types within the DSM category

The two graphs below breakdown the DSM appliance loads by appliance type. Graph 14 shows the average values for each individual DSM appliance type. Graph 15 sums them up in a stacked chart showing the averaged sum total of the DSM appliances.



Graph 14

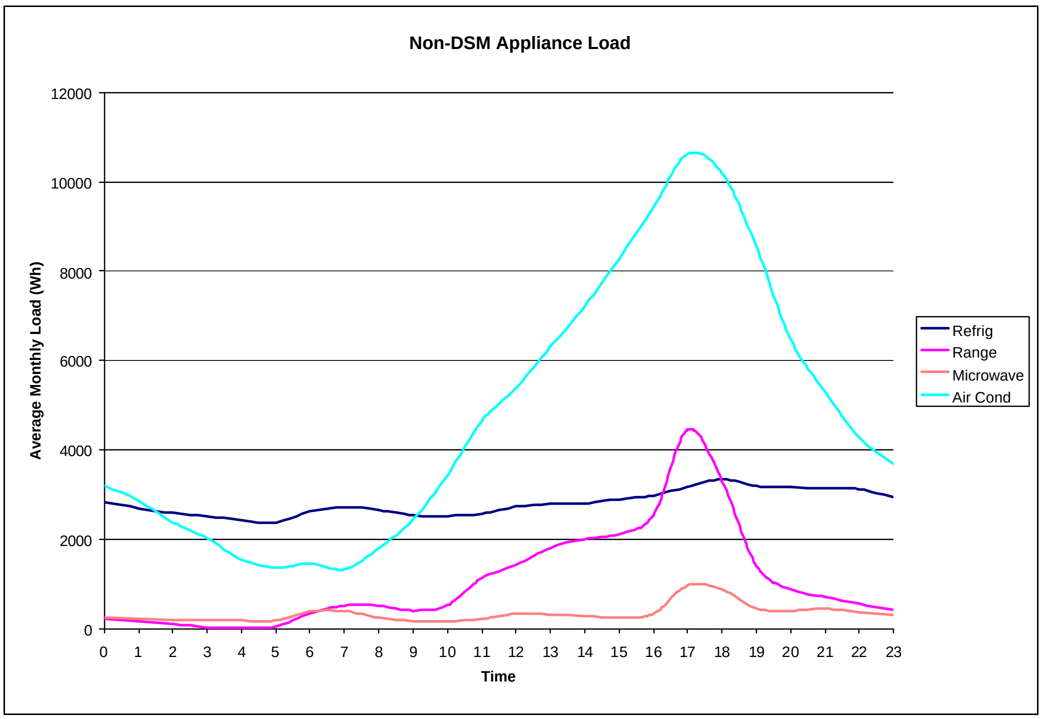


Graph 15

Breakdown of the non-DSM appliances

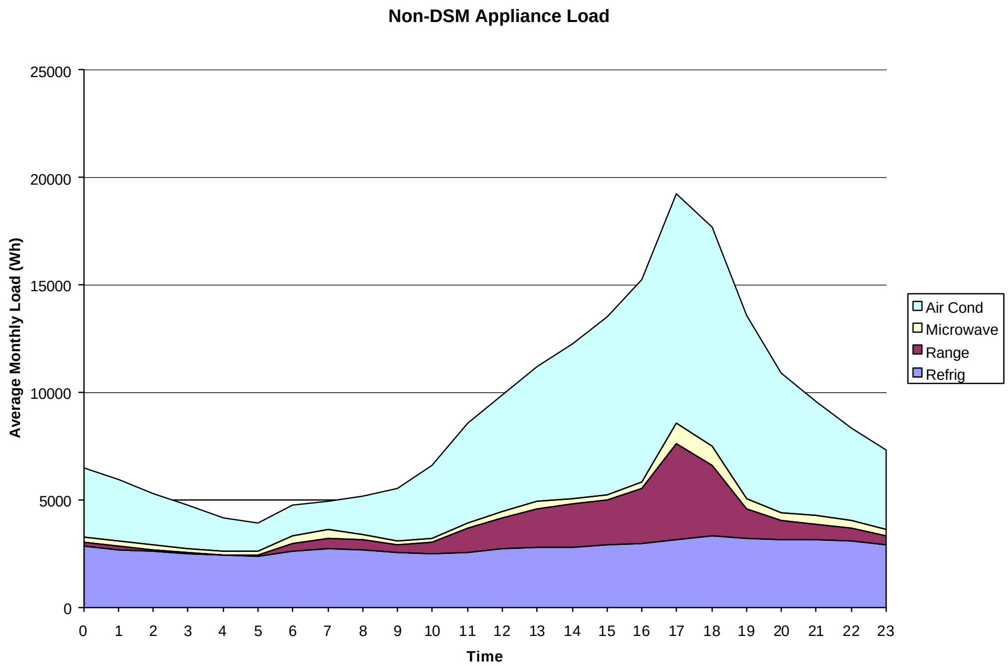
Graphs 16 and 17 illustrate the consumption breakdown for the other individually measured appliances and AC. Here we see the expected AC rise in the afternoon. Data observations from the range, microwave and refrigerator:

- Family wake-up time as indicated by a small rise around 6:00am in all three appliances
- Average supper time or home arrival around 5:00pm by noting another corresponding rise in the refrigerator, range and microwave.
- Singling out the refrigerator line you can observe the small rise likely caused by door openings in the morning and evening indicating the presence of hungry family members either eating or holding the door open to determine what may appeal to the taste buds at that particular moment.



Graph 16

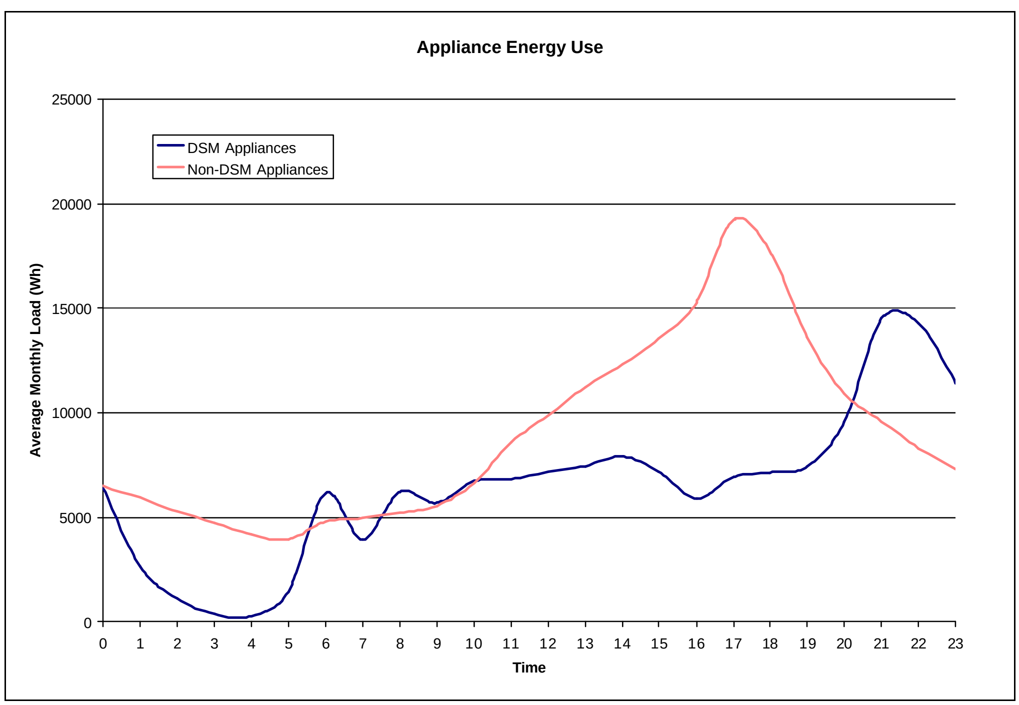
The y-axis represents the averaged monthly amount of electricity consumed in that hour. Time period is Jan –Dec 2005.



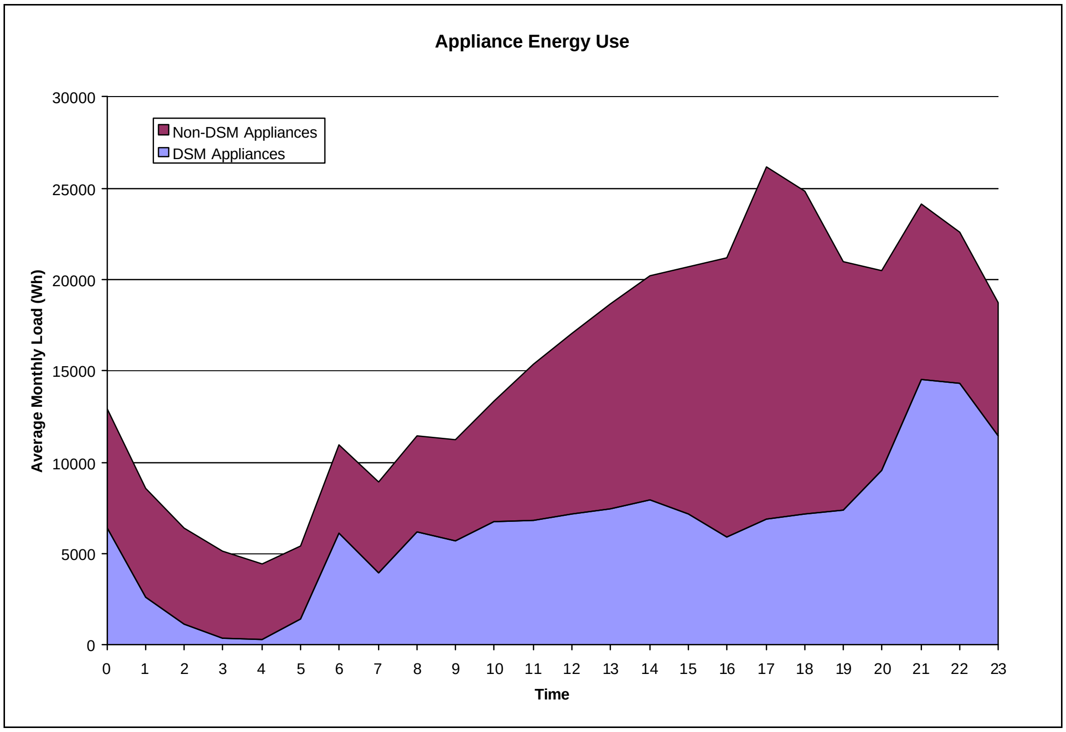
Graph 17

Graph 17 is the stacked representation of the data in graph 16.

Overall comparison of DSM with non-DSM appliance load curves (all days)



Graph 18

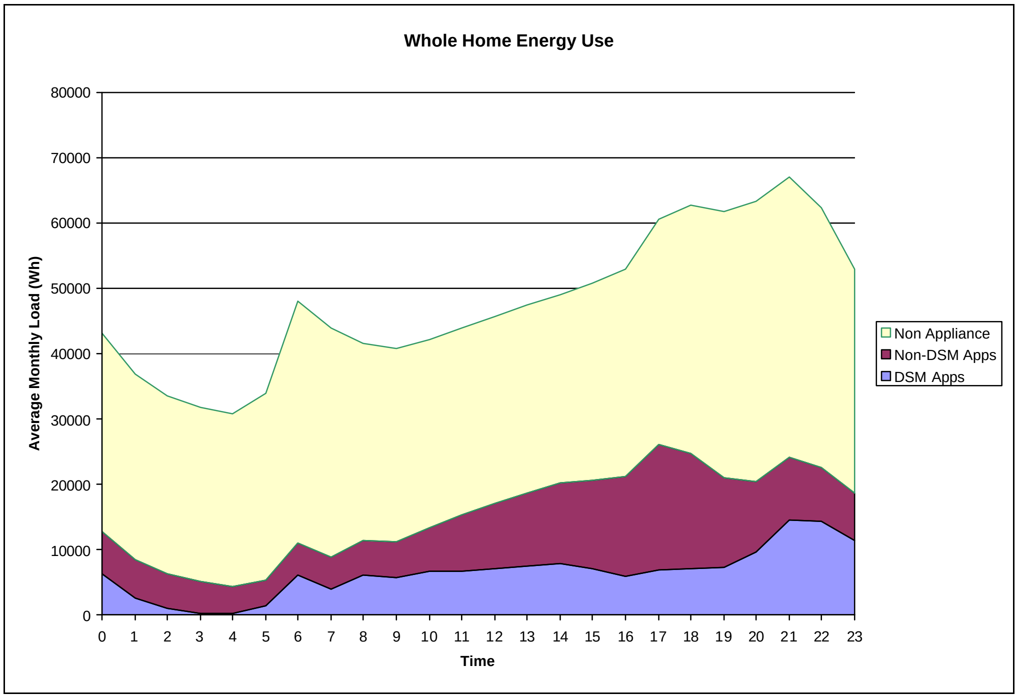


Graph 19

Overall, graphs 18 & 19 compare DSM appliances with the other appliances involved in this study. Time period is Jan – Dec 2005. DSM appliances are washer, dryer, dishwasher. Non-DSM appliances are refrigerator, range, microwave, and air conditioner.

As noted earlier, a control group of homes with non-DSM versions of the same appliances would provide a better comparison. However, even with a control group, a statistically significant comparison would require involvement of many more households. For the purpose of this study we refer you to the **ELCAP**[1] study and the **Parker**[2] study each of which details sub-metered residential electric use. (Further information on these two studies can be found on page 99 .) As shown in these graphs the DSM appliances favor off-peak use when averaged over the entire month (peak & off-peak).

Graph 20 (below) adds the rest of the home data into the graph. Looking at graph 20, I have to ask the question; did the consumers' awareness of the need to shift energy to after 9:00pm have an impact on other energy-consuming aspects of their home and lifestyle? These consumers had an extraordinary understanding of the problem via their thorough education. They had ample reminders via the DSM appliances, and the energy monitor that showed red/green for peak and off-peak along with the current and historical cost detail for their household. Did this also influence the consumer to conserve in other manual ways? Several comments in the survey may touch on this aspect to some degree (see "Woodridge participants closing interview summary:" on page 89).



Graph 20

Seasonal load curves by appliance:

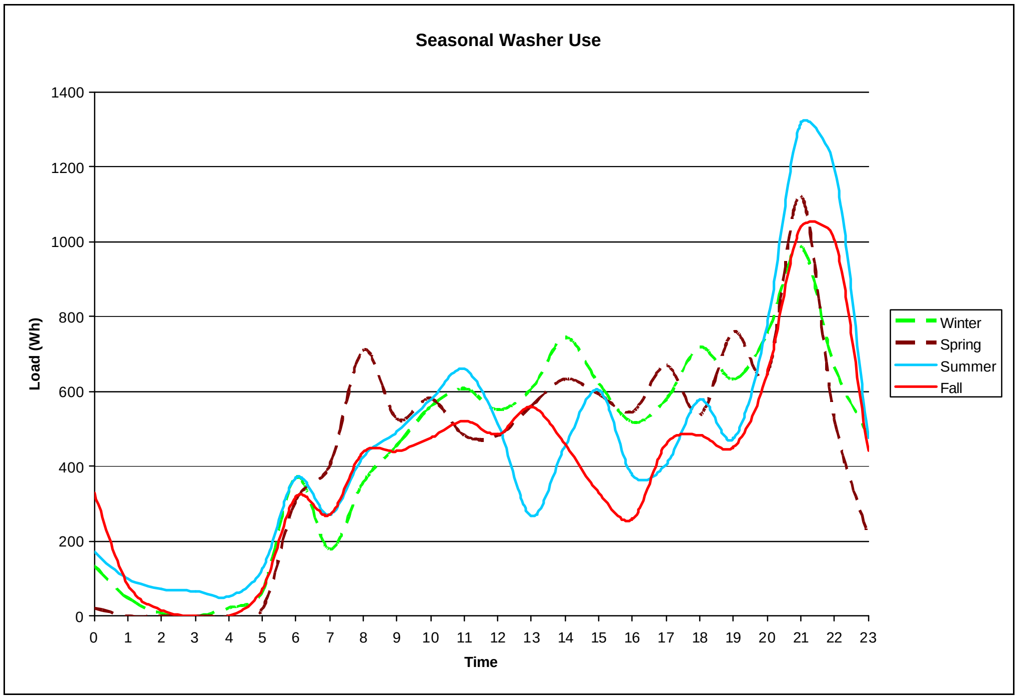
In the graphs below, the seasons are defined as follows:

- Winter is Dec, Jan, Feb
- Spring is Mar-May
- Summer is Jun-Aug
- Fall is Sep-Nov

The project team feels the small sample size significantly impacts the results of the seasonal data graphs. In other words, more homes would smooth out the seasonal graphs providing a more accurate set of averages. With this understanding however, the seasonal graphs below are offered for review as the team feels there is still value in observing seasonal differences in this small set of four homes.

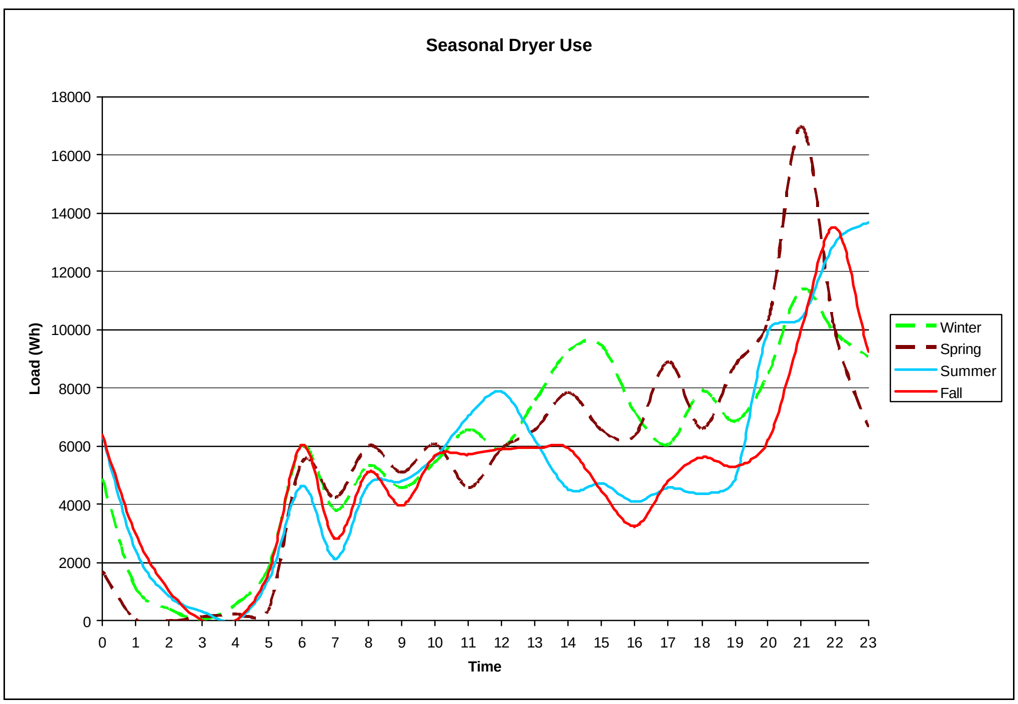
Seasonal appliance averages combined weekend/weekday

Washer : Seasonal



Graph 21

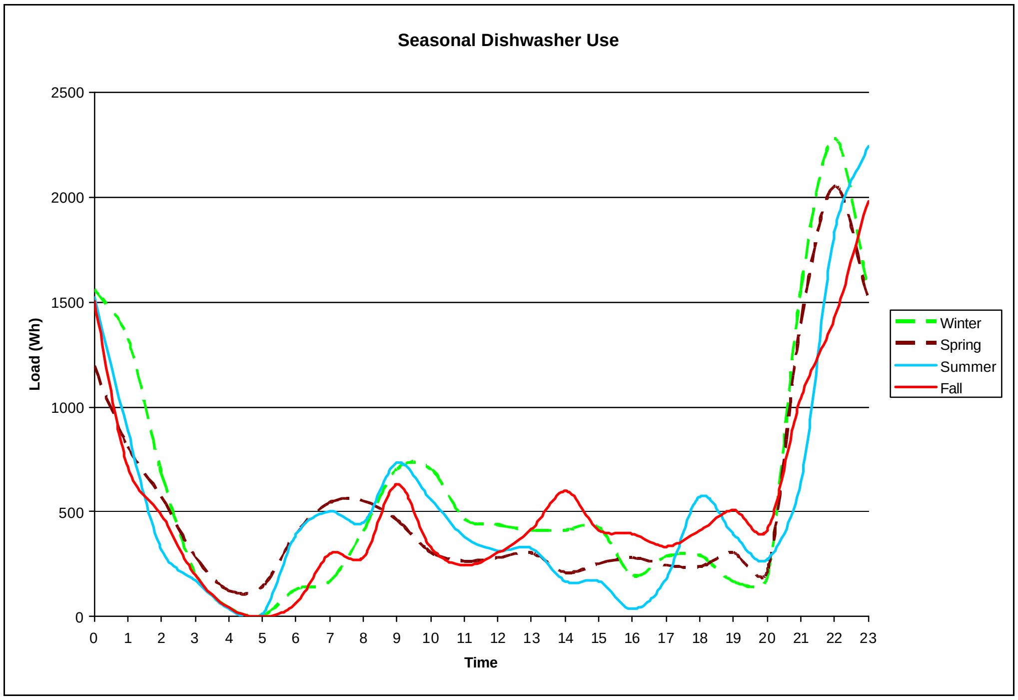
Dryer : Seasonal



Graph 22

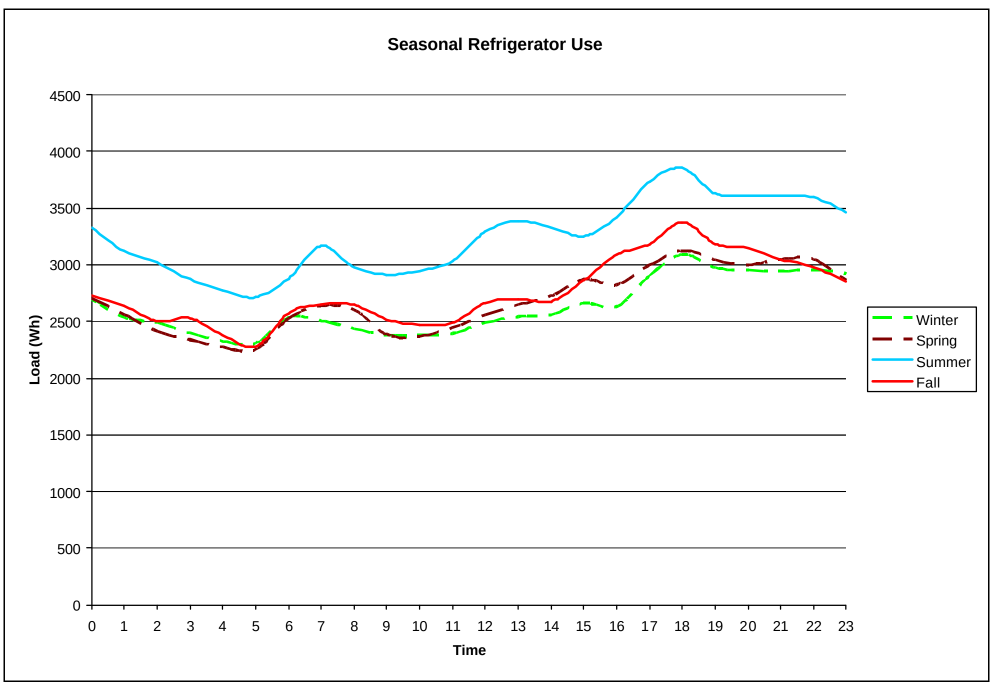
At first glance, the Washer/Dryer/Dish seasonal load curves look surprising with the shift to the end of the day. But note that these three appliances had the automatic delay buttons and were used by consumers who had been well informed of the time-of-use rate structure.

Dishwasher : Seasonal



Graph 23

Refrigerator : Seasonal

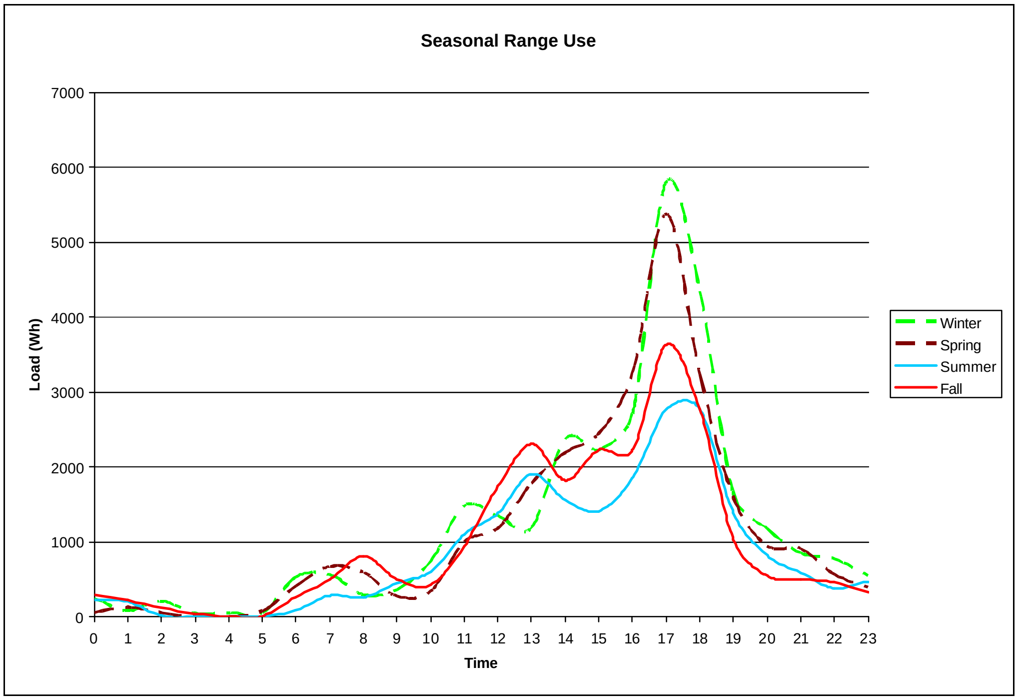


Graph 24

Note that every home in the study was air conditioned leaving the temperature in the homes within a comfortable range year round. Summer indoor temperature may be a few degrees warmer but not substantially different. Based on this information, you could assume that refrigerators would not be significantly different in the seasonal graphs. Yet we see notable rise during the summer months shown in the blue line in graph 24. Refrigeration researchers at Whirlpool attribute this summer rise to a higher humidity. Although the temperature in the home may not be significantly higher during the summer, higher humidity alone will cause this effect.

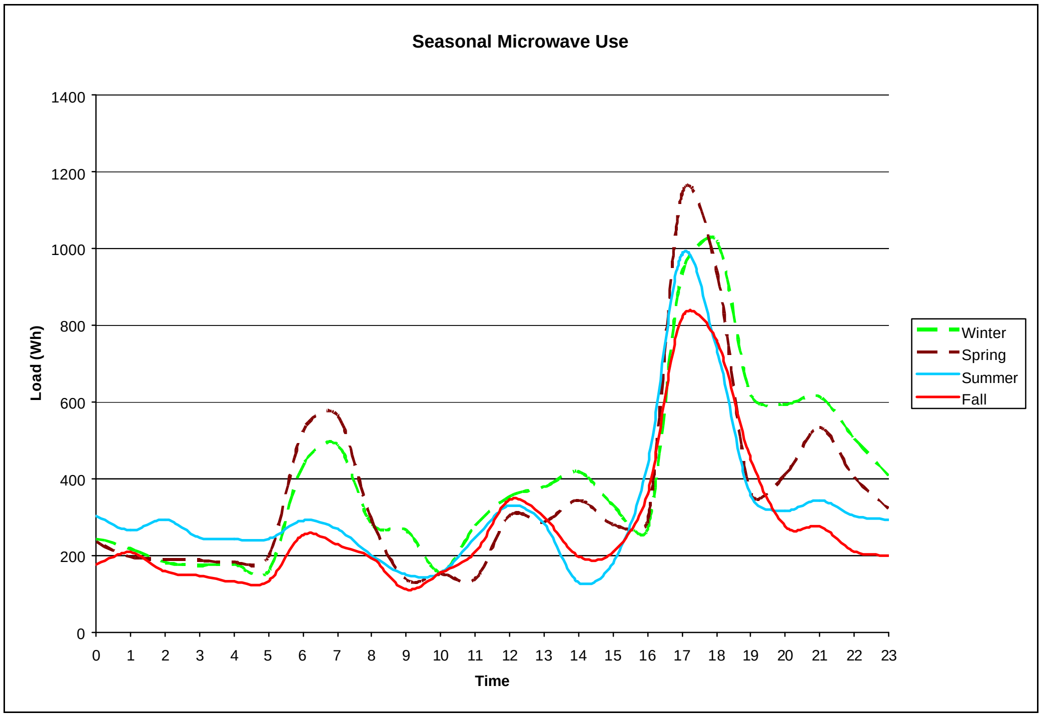
For the range of seasonal data in Graph 25, it is apparent that these consumers did less cooking during summer and fall seasons.

Range : Seasonal



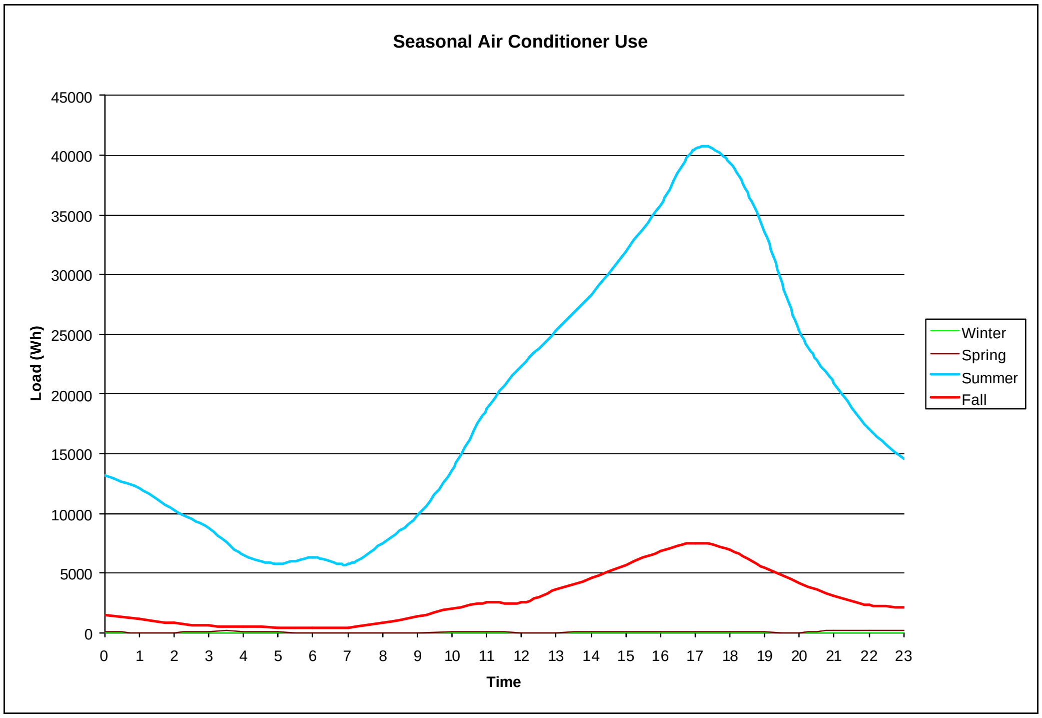
Graph 25

Microwave : Seasonal



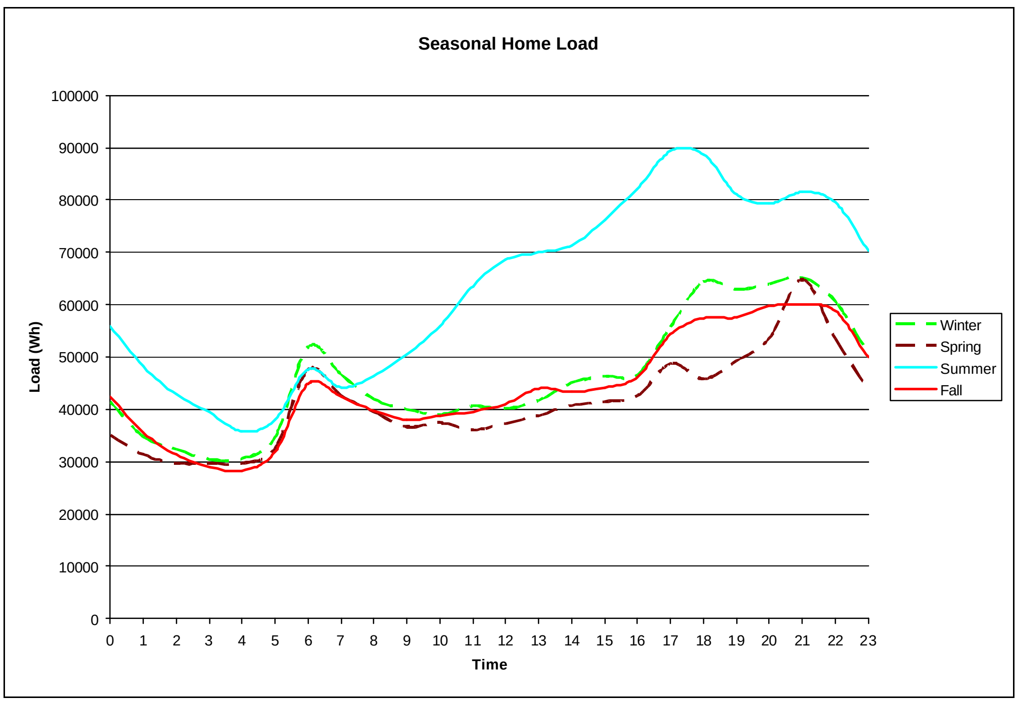
Graph 26

Air Conditioner : Seasonal



Graph 27

Total Home Load : Seasonal



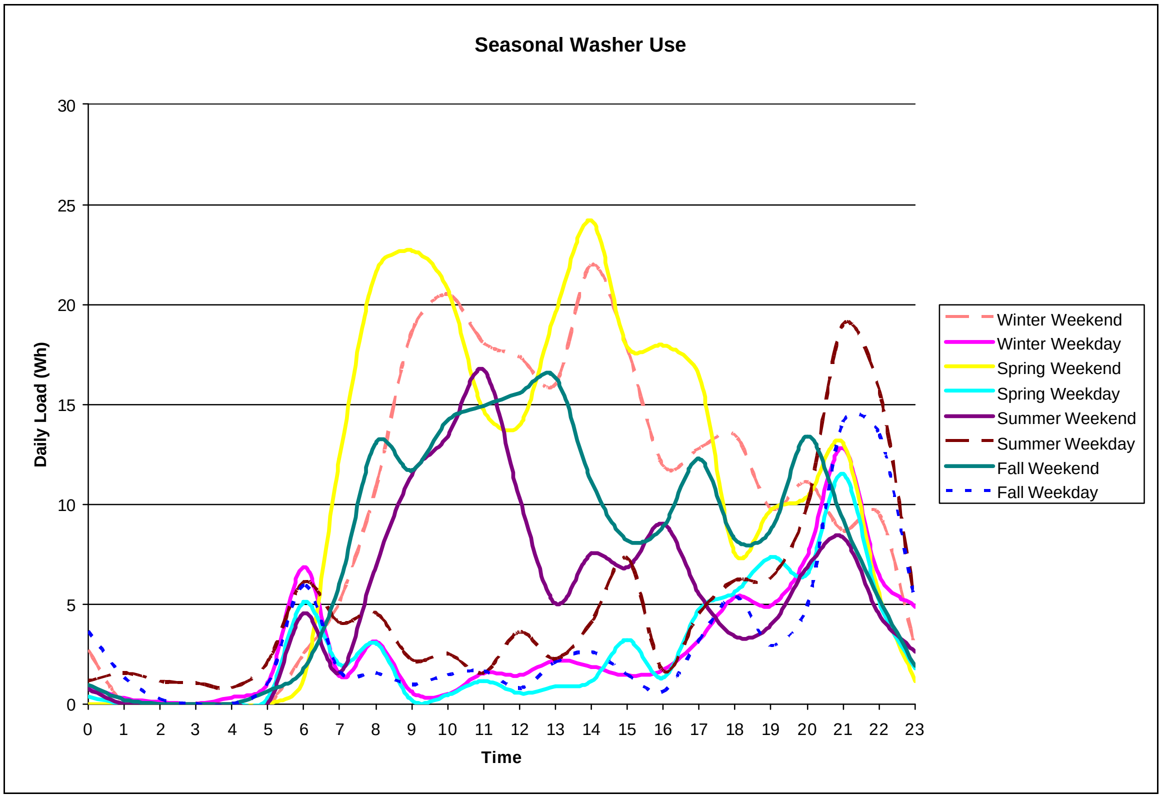
Graph 28

Seasonal by appliance with weekend / weekday comparison

This set of graphs breaks down the weekend/weekday use of each appliance by season. In these graphs, the seasons are defined as follows:

- Winter is Dec, Jan, Feb
- Spring is Mar-May
- Summer is Jun-Aug
- Fall is Sep-Nov

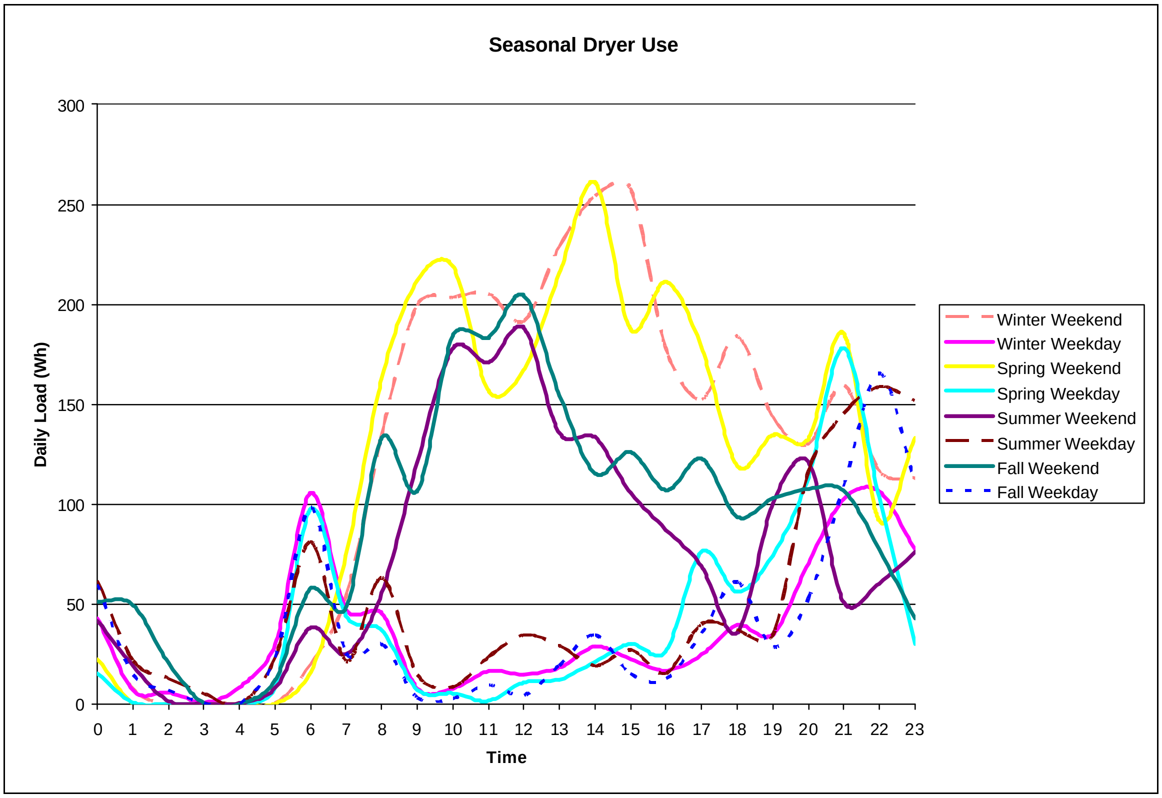
Washer : Seasonal by weekday / weekend



Graph 29

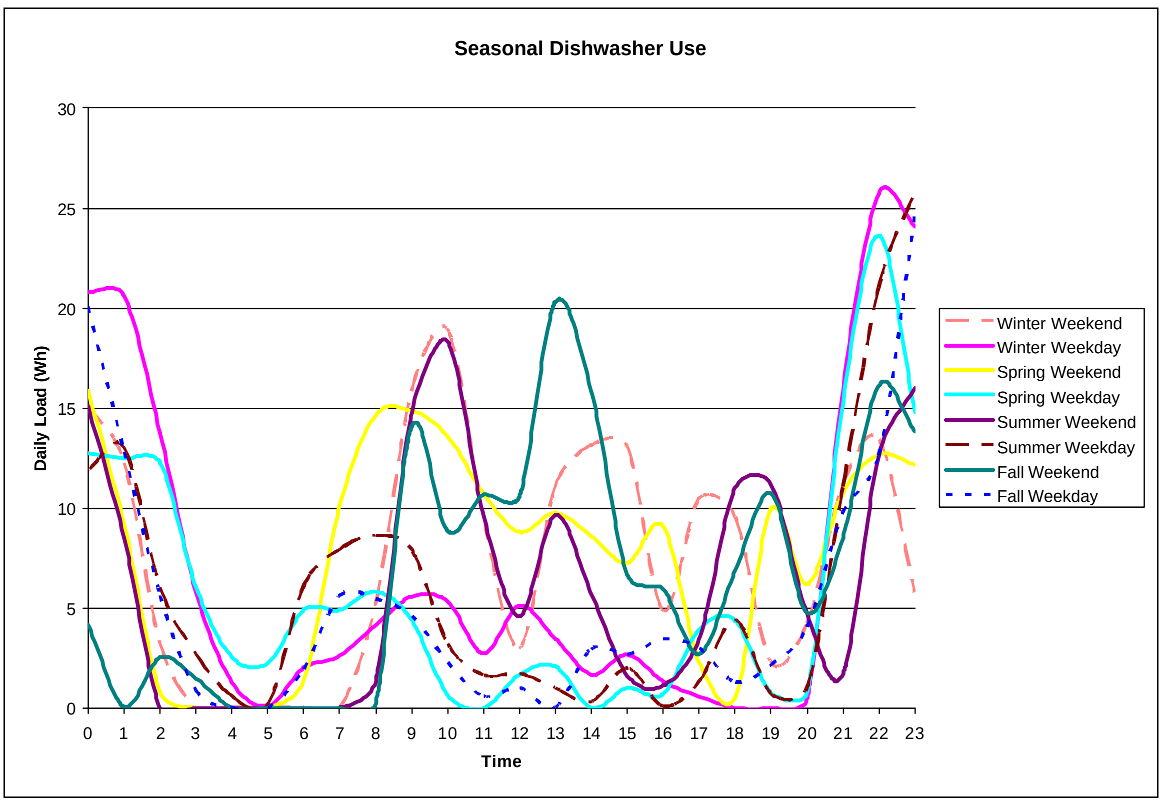
As we would expect by this point in our understanding of the graphs, with the DSM appliances (Wash/Dry/Dish), we see more contrast in the usage pattern between weekday and weekend. Weekend use shows peaks in mid-day while weekdays tend to have peaks later in the evening.

Dryer: Seasonal by weekday / weekend



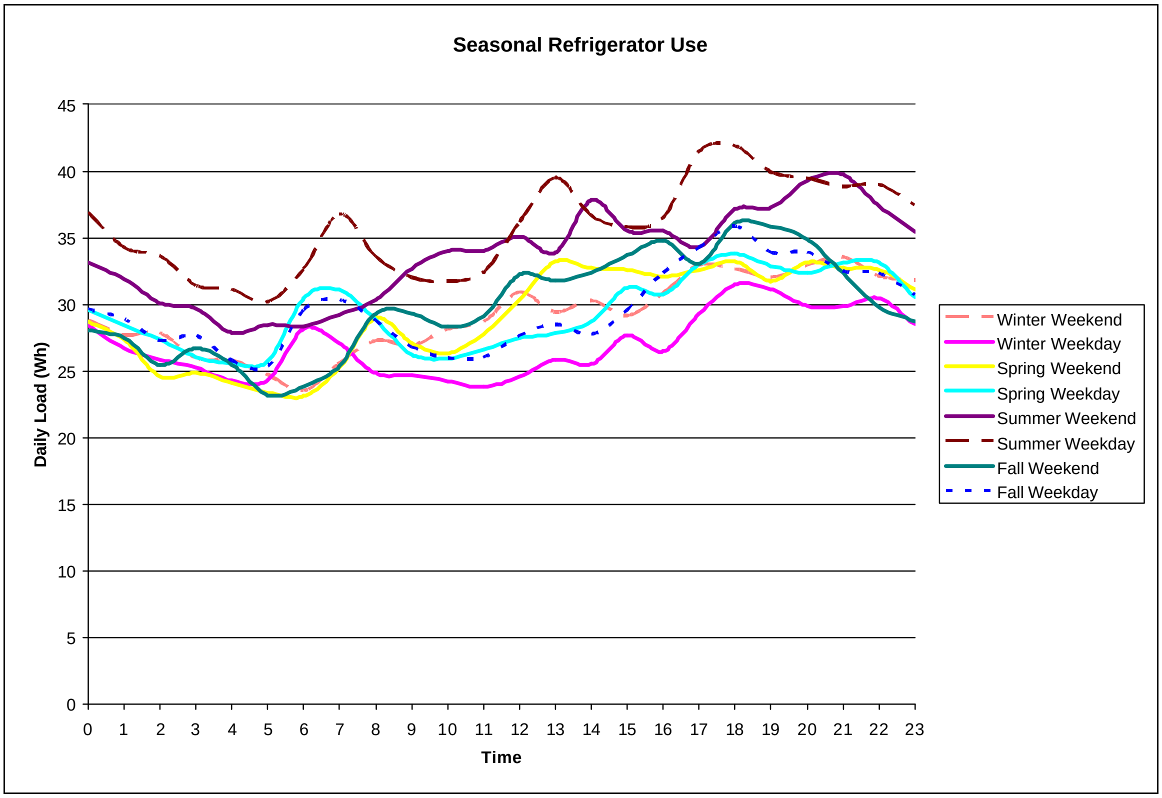
Graph 30

Dishwasher: Seasonal by weekday / weekend



Graph 31

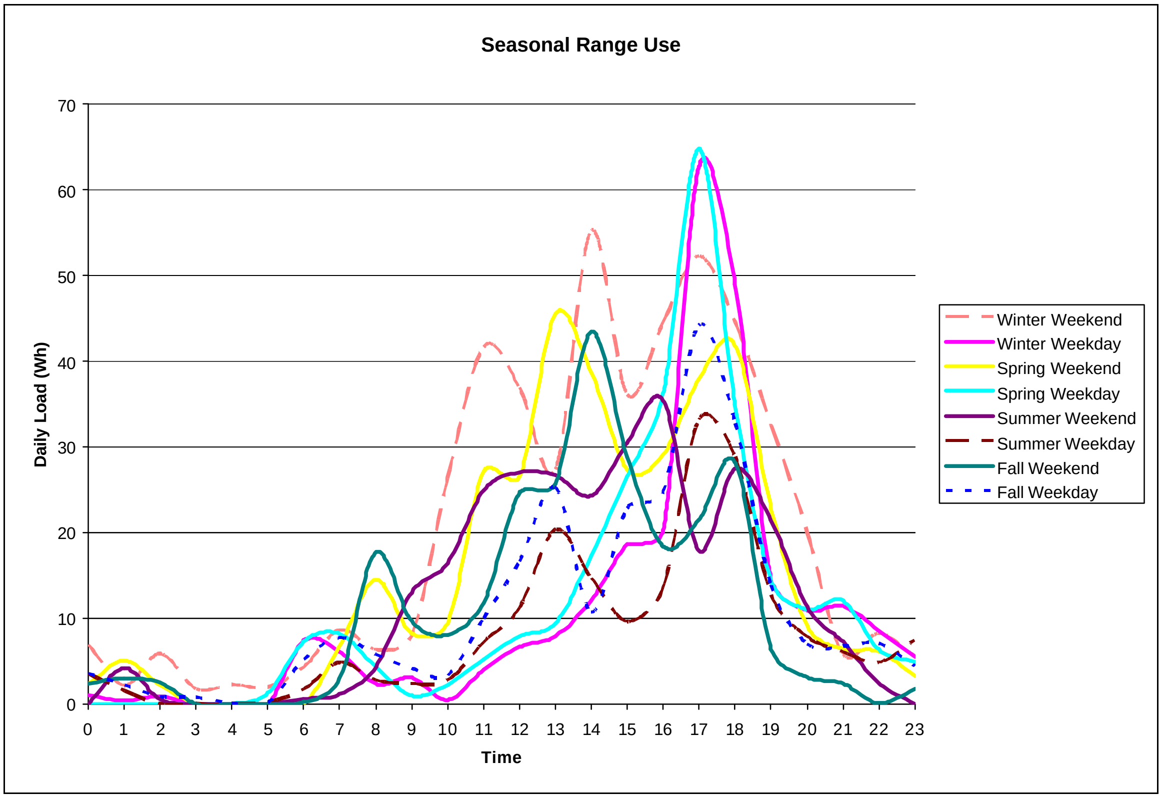
Refrigerator: Seasonal by weekday / weekend



Graph 32

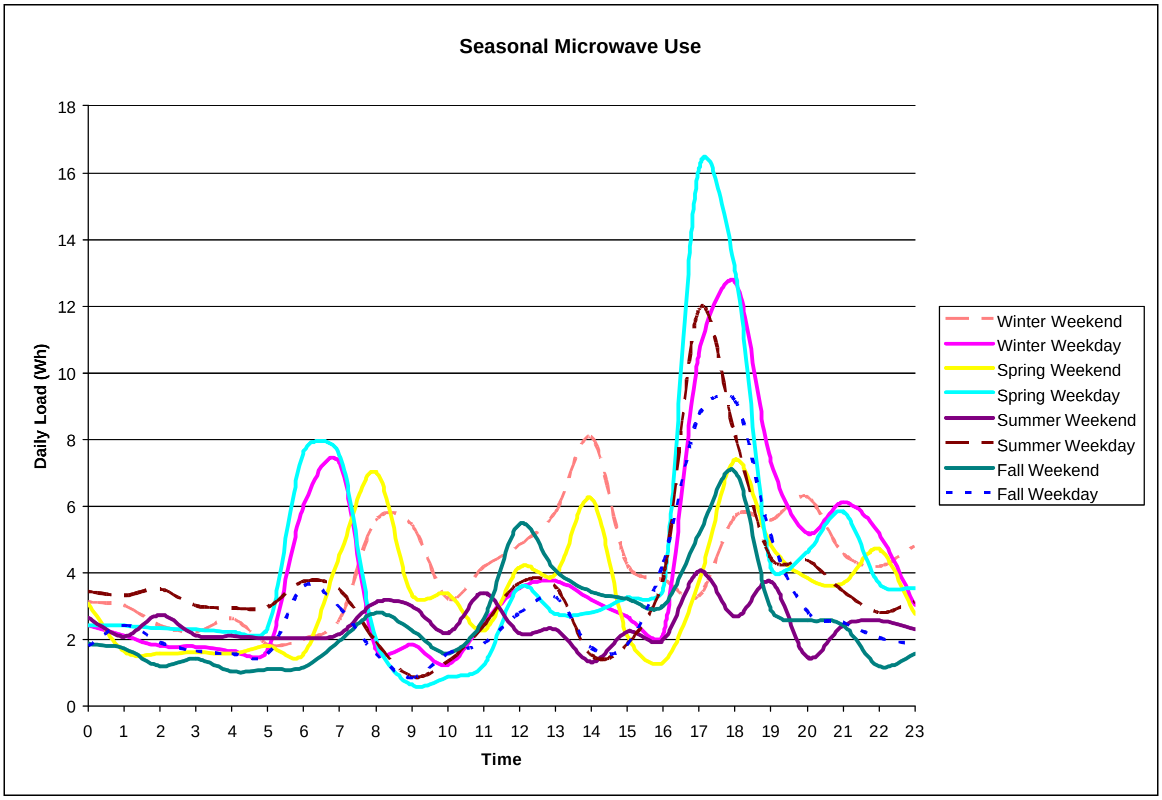
As in the composite refrigerator graph, the summer season stands out for both weekday and weekend consumption while winter use is clearly below the other seasons. An interesting observation is the summer weekend line that rises much later in the day. Future studies may want to tie in additional data on refrigerator usage. For example, if we also had door openings and the temperature both inside and outside the refrigerator, lifestyle data could be added to the mix. At this point we can only suspect what consumer behaviors may contribute to the differences.

Range: Seasonal by weekday / weekend



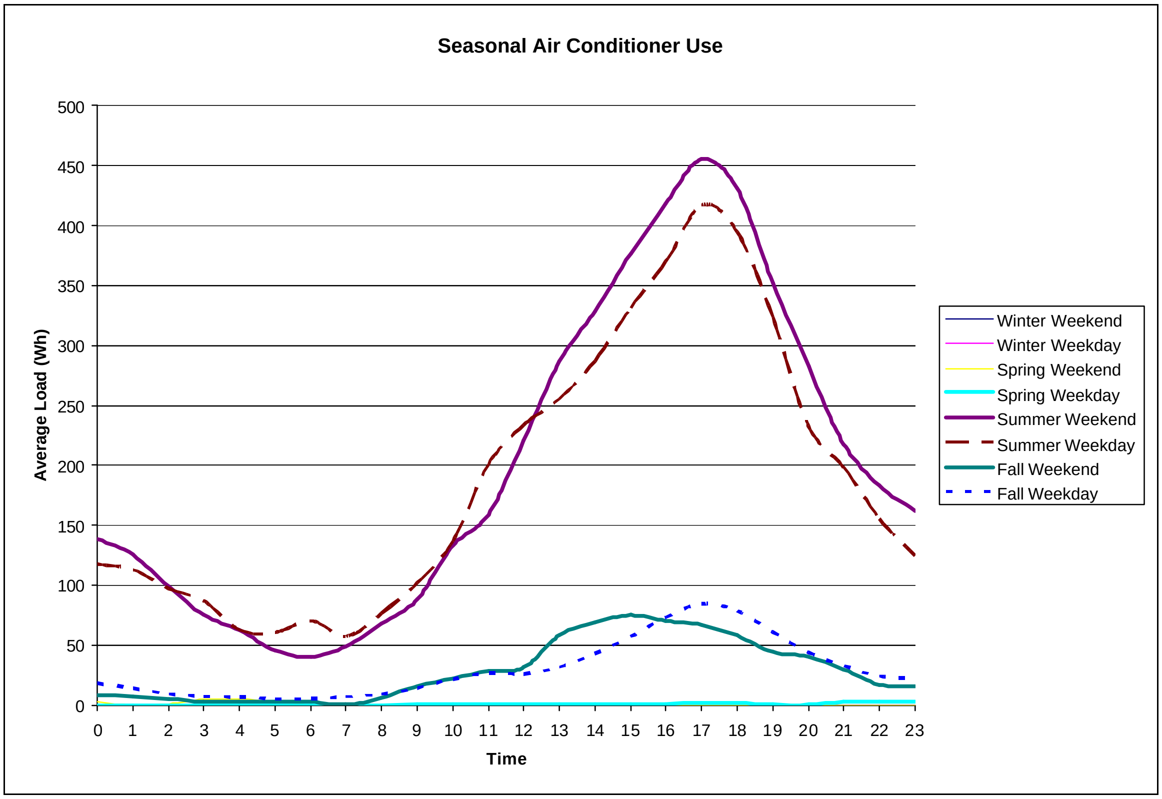
Graph 33

Microwave: Seasonal by weekday / weekend



Graph 34

Air conditioner: Seasonal by weekday / weekend



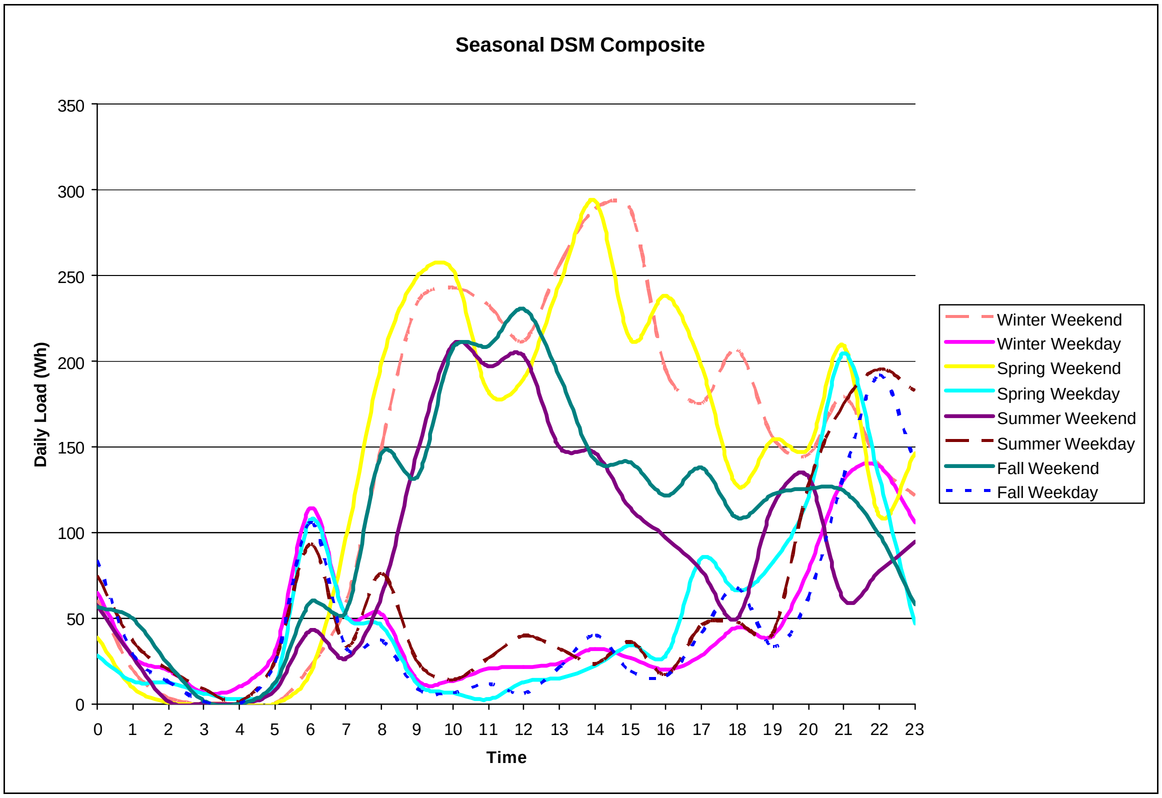
Graph 35

Seasonal comparison of DSM & non-DSM weekend and weekday

This set of graphs breaks down the weekend/weekday use of DSM and non-DSM appliances by season. Appliances with the DSM feature are the washer, dryer, and dishwasher. In these graphs, the seasons are defined as follows:

- Winter is Dec, Jan, Feb
- Spring is Mar-May
- Summer is Jun-Aug
- Fall is Sep-Nov

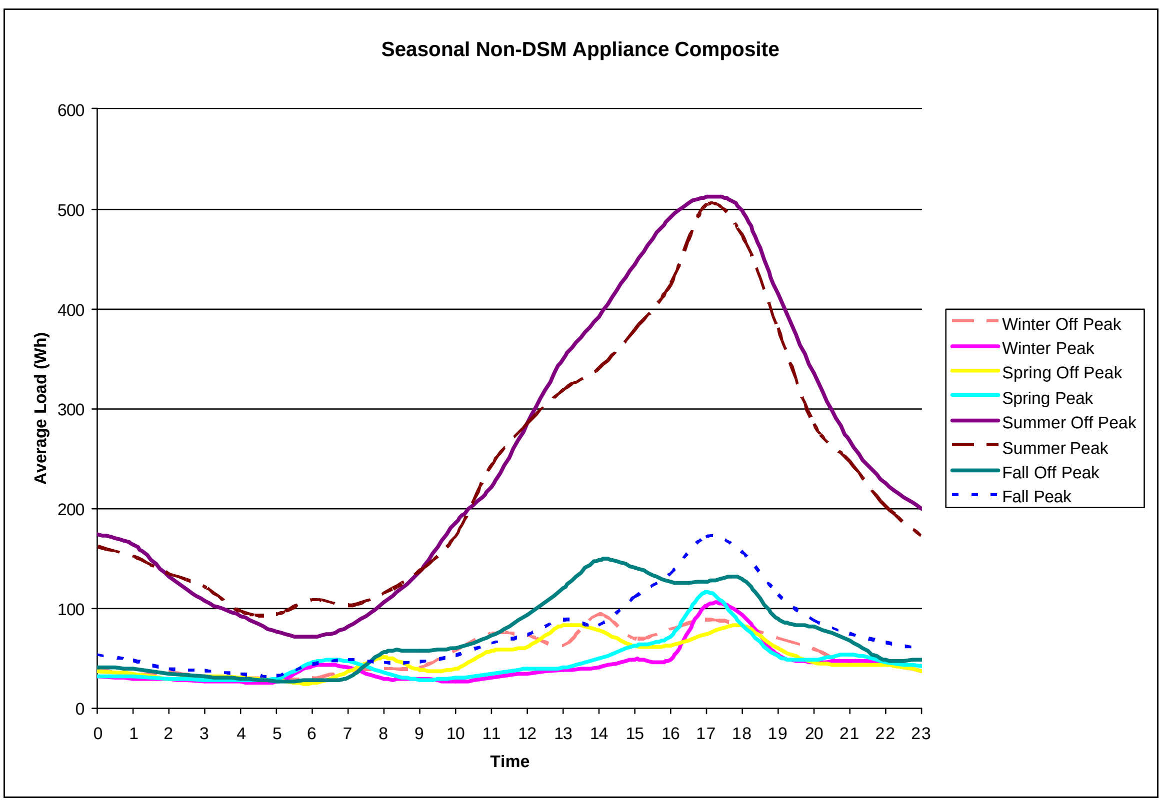
DSM appliances: Seasonal by weekday / weekend



Graph 36

DSM appliances were Washer, Dryer & Dishwasher

non-DSM appliances : Seasonal by weekday / weekend

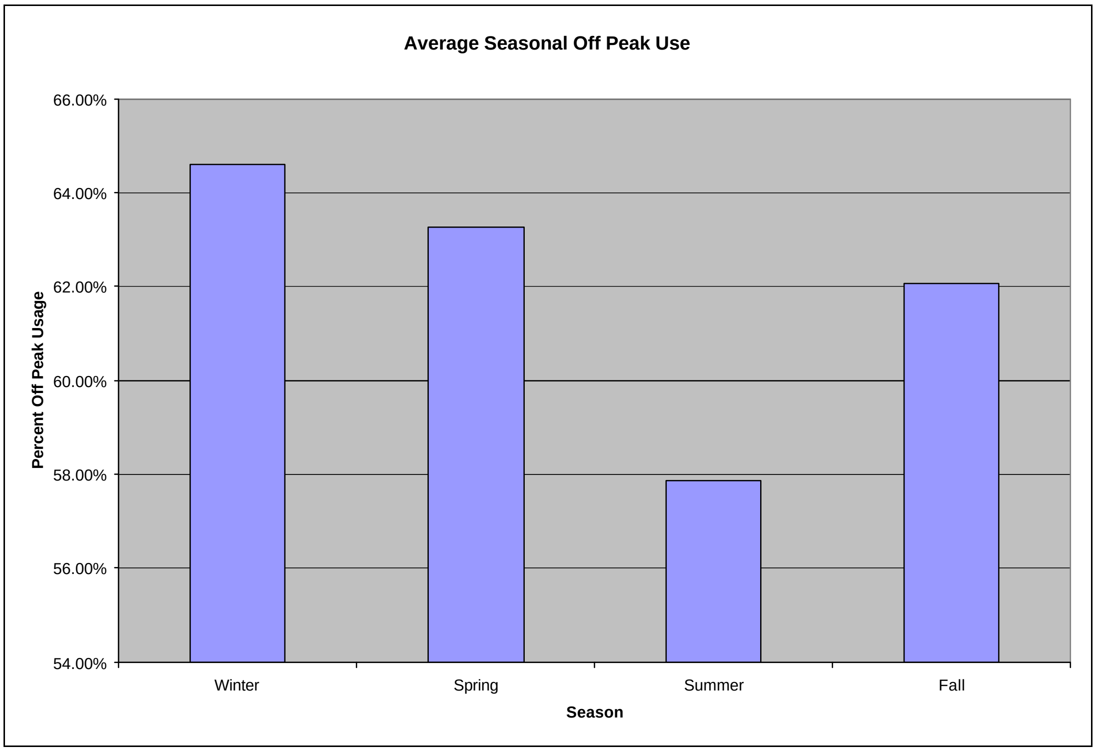


Graph 37

Non DSM appliances are refrigerator, range, microwave, and air conditioner. With the air conditioner load, the non-DSM group shows the sharp rise during the summer afternoons.

Total home off-peak: seasonal

From the graph below showing the seasonal off-peak use, summer appears to be the more difficult time to shift load. Air conditioning would seem the obvious reason. In addition to AC, we found that families with school-aged children will be home more during the summer and want to make effective use of their time. This includes doing laundry as well as other electrical loads caused by more home occupancy. This was verified both in the data as well as consumer interviews.

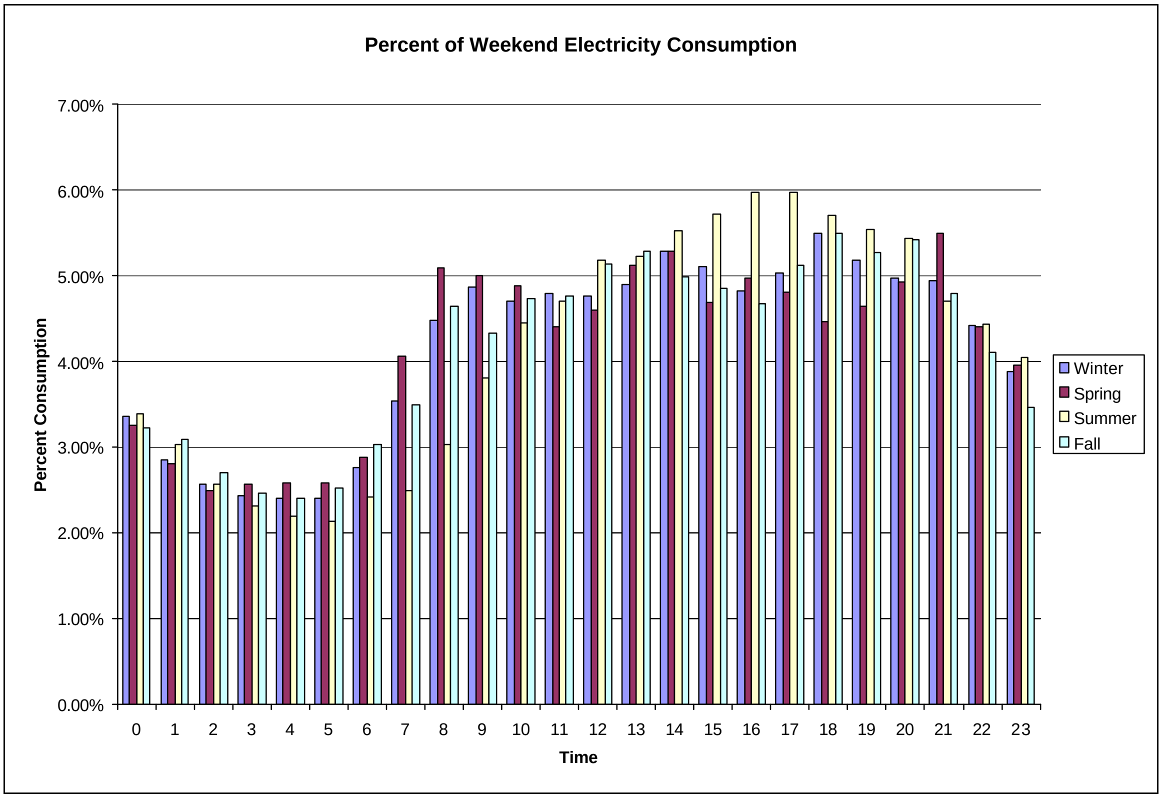


Graph 38

Graph 38 indicates that during the summer season, less than 58% of the energy was consumed during off-peak hours compared with more than 64% during the winter.

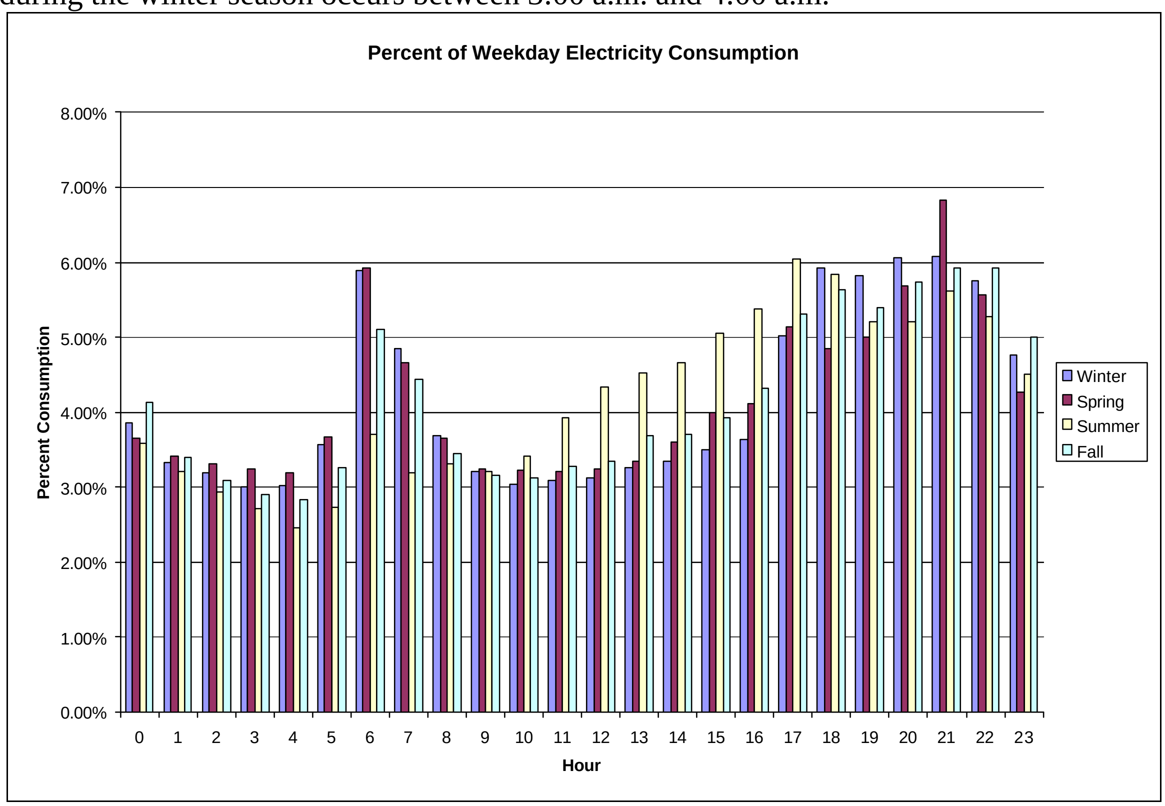
Total home: seasonal weekend / weekday bar graphs

The graph below shows a comparison of each hour of the averaged weekend load curve by season. Although this data appears in previous graphs, the side-by-side comparison of seasons for the same hour of the day becomes easier to understand in graphs 39 and 40. The percentages shown on the y axis at the left represent the percent of the daily load used during that hour. In other words, if you were to sum up all the blue bars (representing the winter load curve) for each hour of the day, it would total 100%.



Graph 39

Similar to the graph above, the values represented in the graph below portray the seasonal load for each weekend hour of the day. For example, we can see that 3% of the average daily energy used during the winter season occurs between 3:00 a.m. and 4:00 a.m.

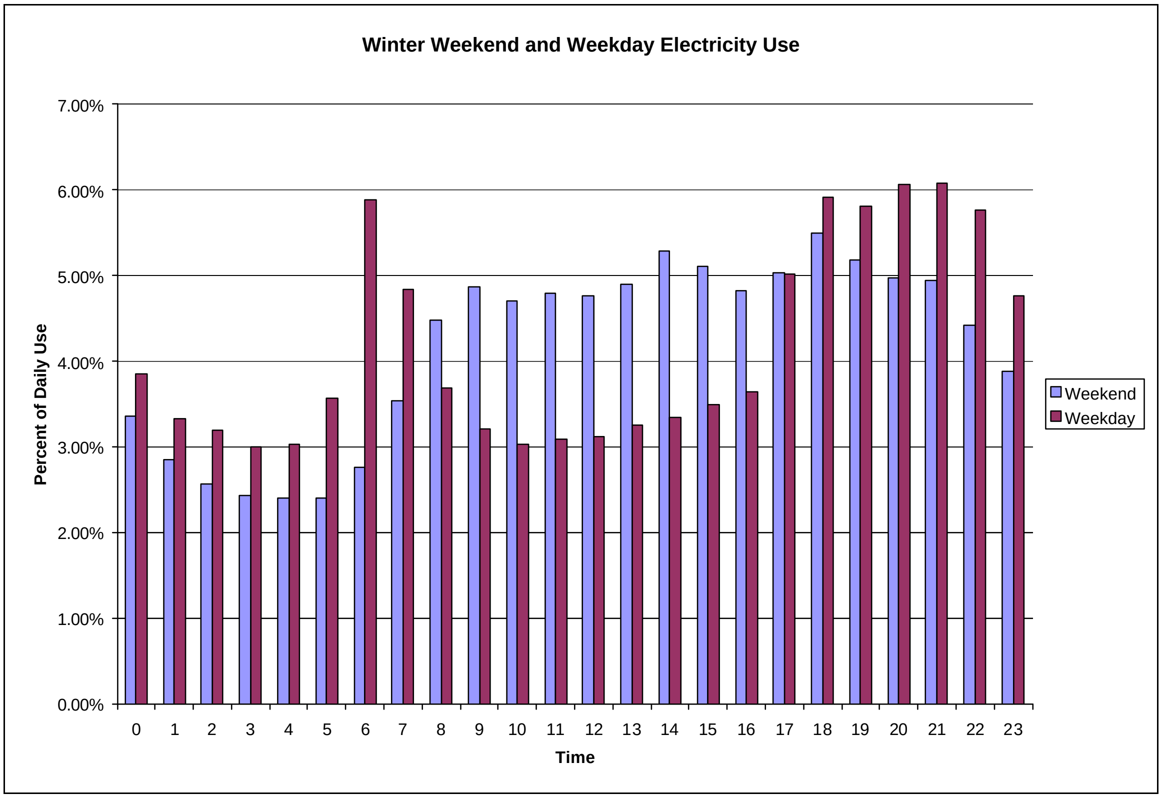


Graph 40

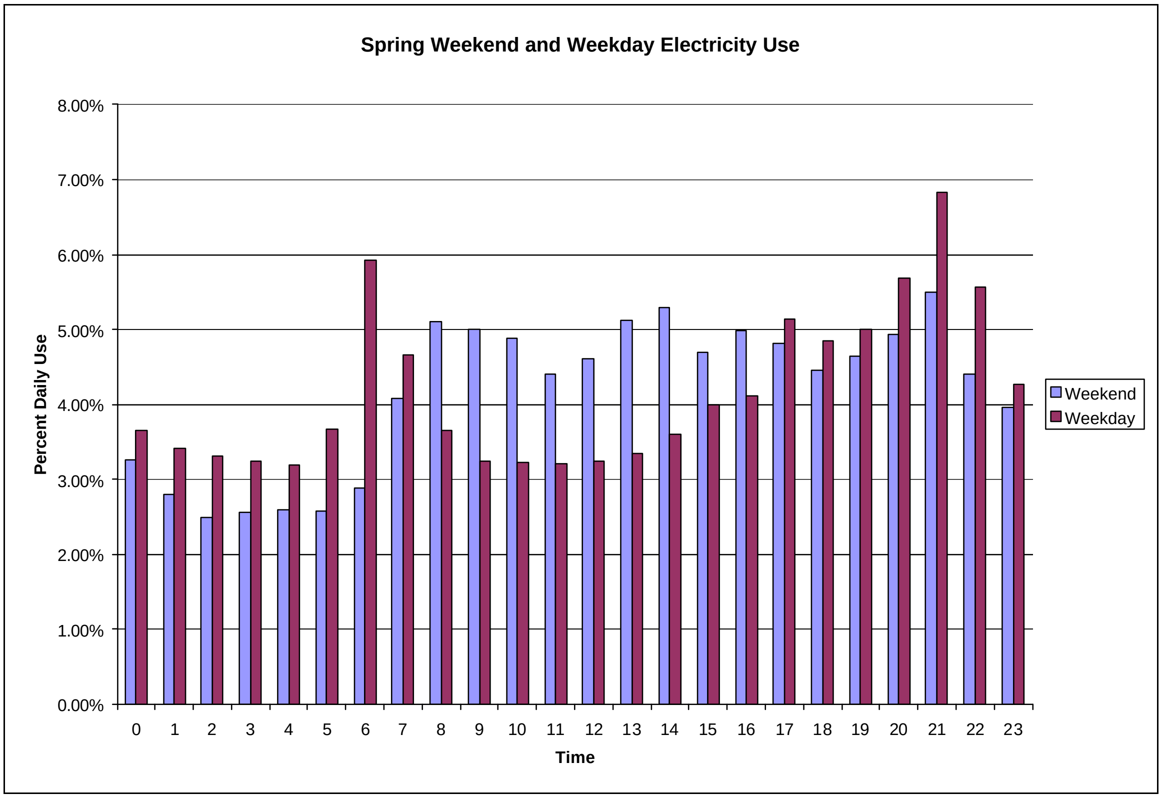
Total home: seasonal weekend / weekday bar graphs

The set of four graphs below (graphs 41-44) simplify a seasonal hour by hour comparison between weekday and weekend consumption. Several interesting observations include:

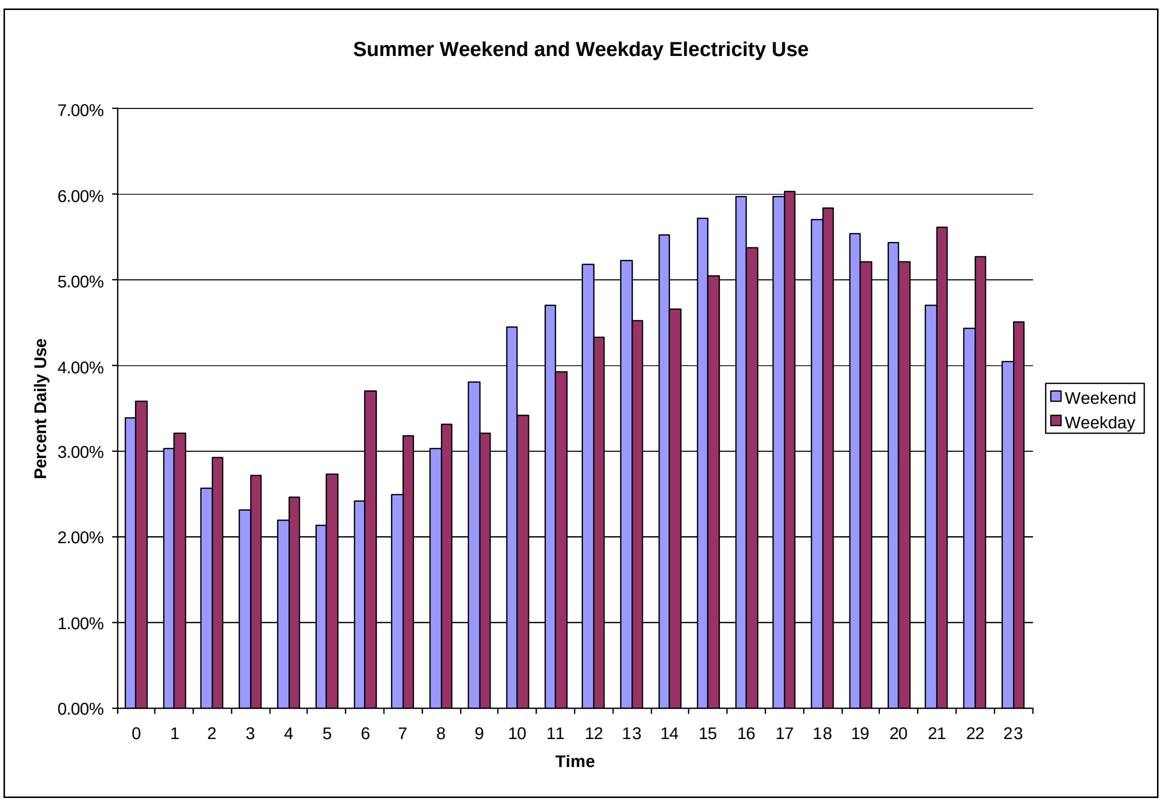
- Fall weekday consumption is high later into the evening. The reasons for this are difficult to guess.
- The summer weekday and weekend patterns, unlike the other 3 seasons, tend to follow similar curves showing less differentiation between weekday and weekend. This again illustrates that families with children (all of participants for this pilot) may find it more difficult to shift consumption during the summer months.



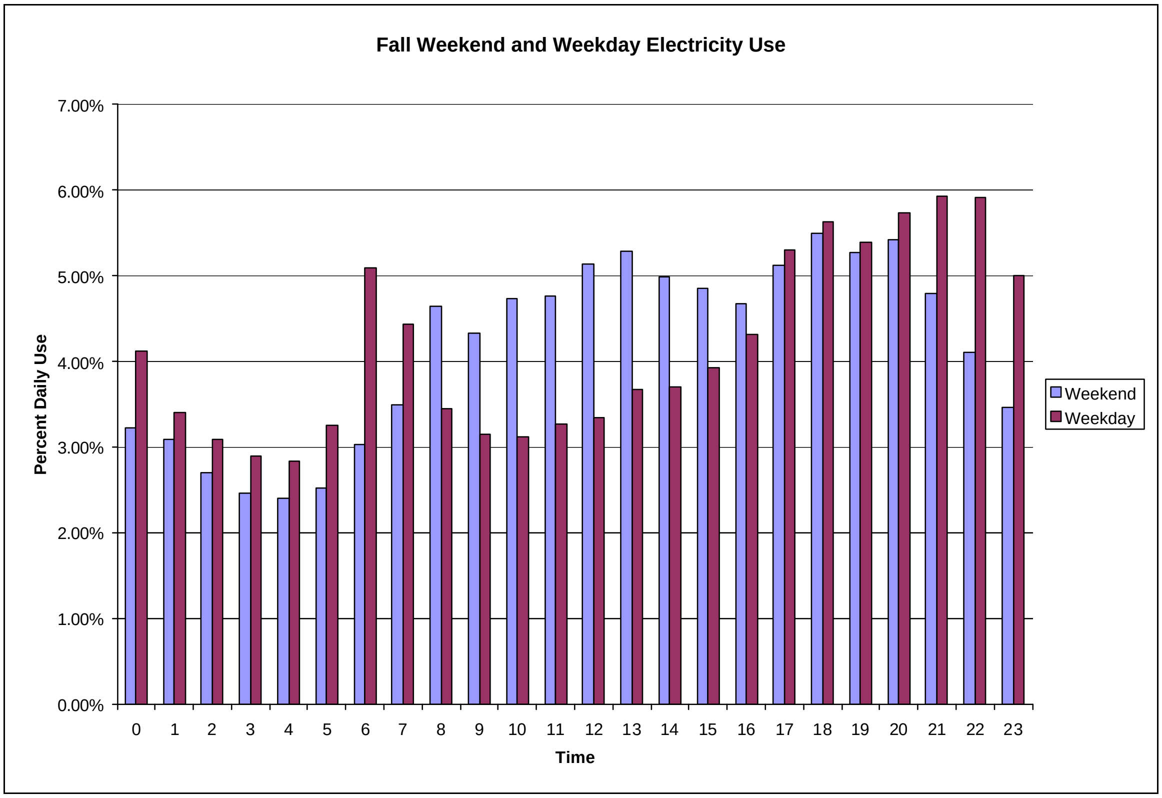
Graph 41 - Winter: December, January, February



Graph 42 - Spring: March, April, May



Graph 43 - Summer: June, July, August

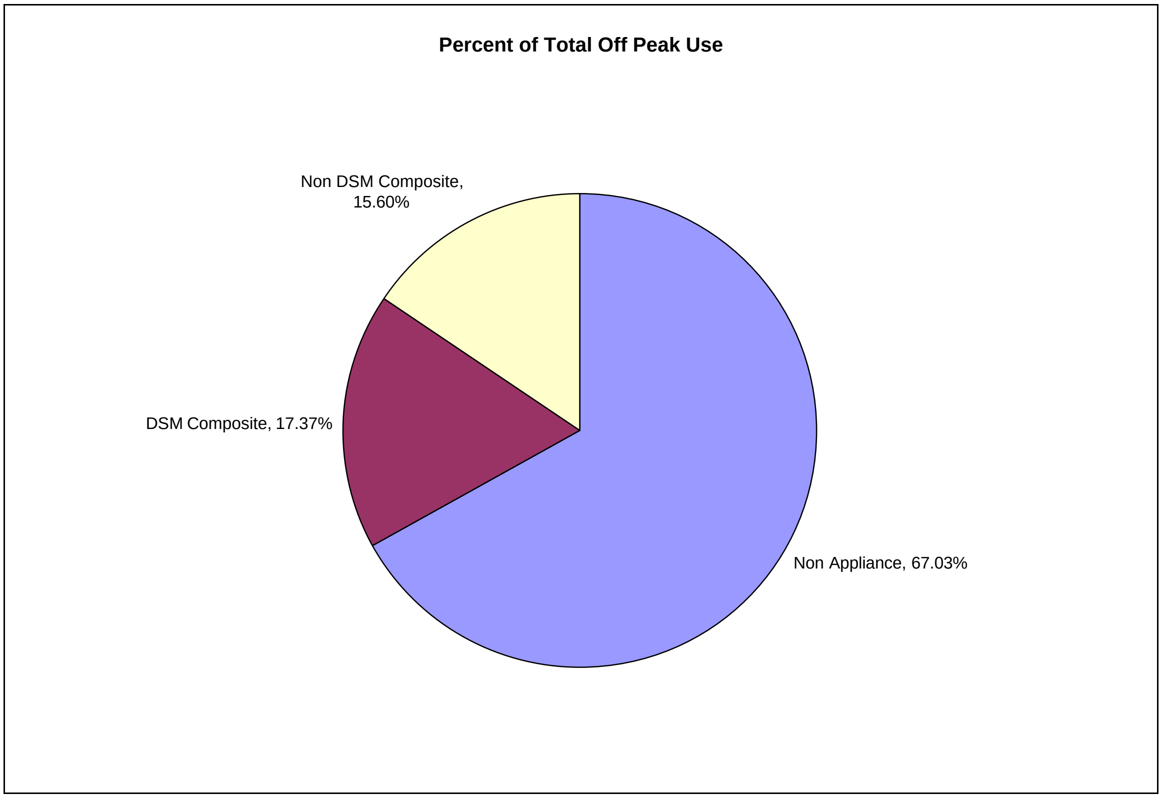


Graph 44 - Fall: September, October, November

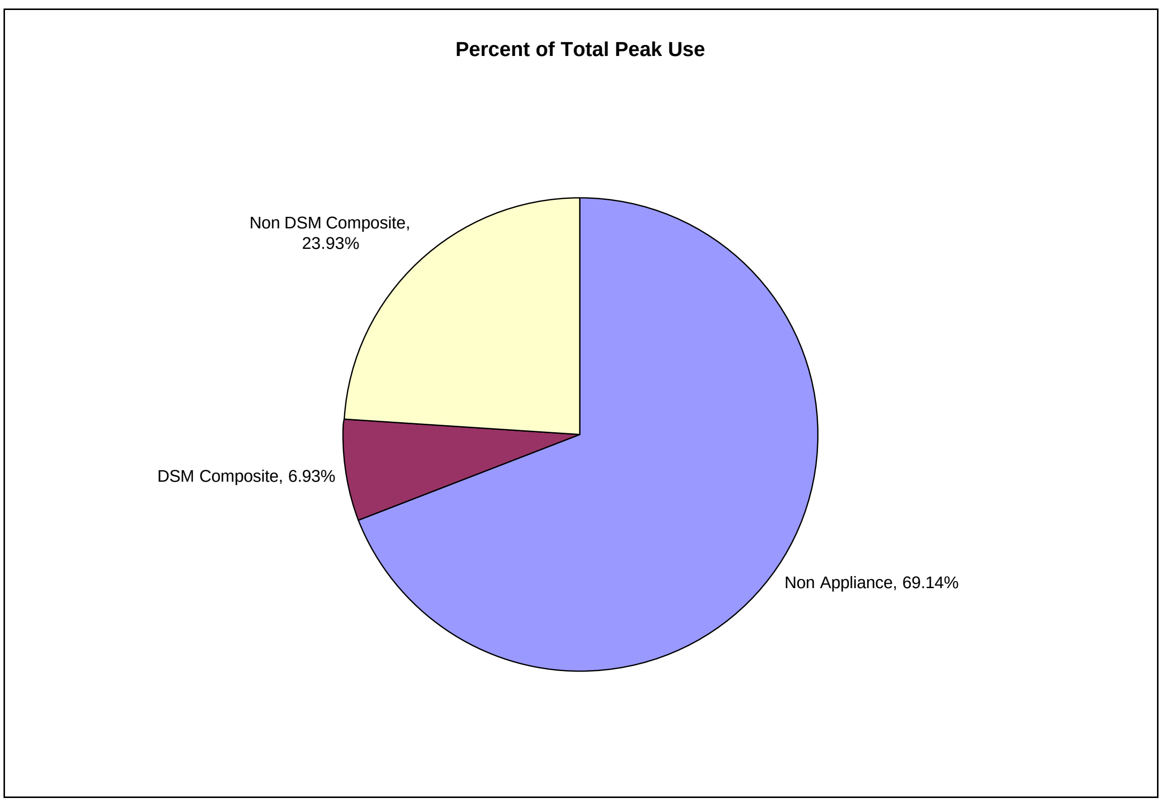
Summarized home data

Total peak and off-peak TOU comparison pie charts

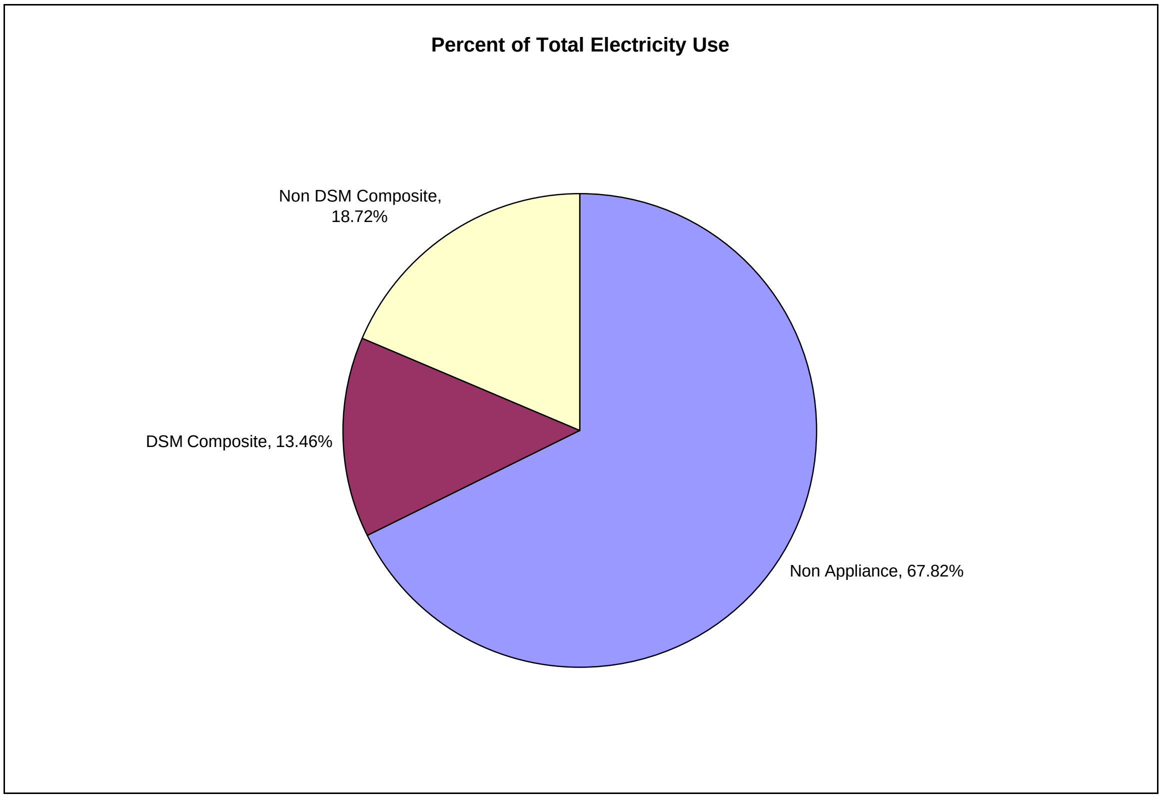
The three pie charts below (graphs 45-47) illustrate the breakdown between DSM / Non-DSM / and Non-appliance use in the summarized home data.



Graph 45

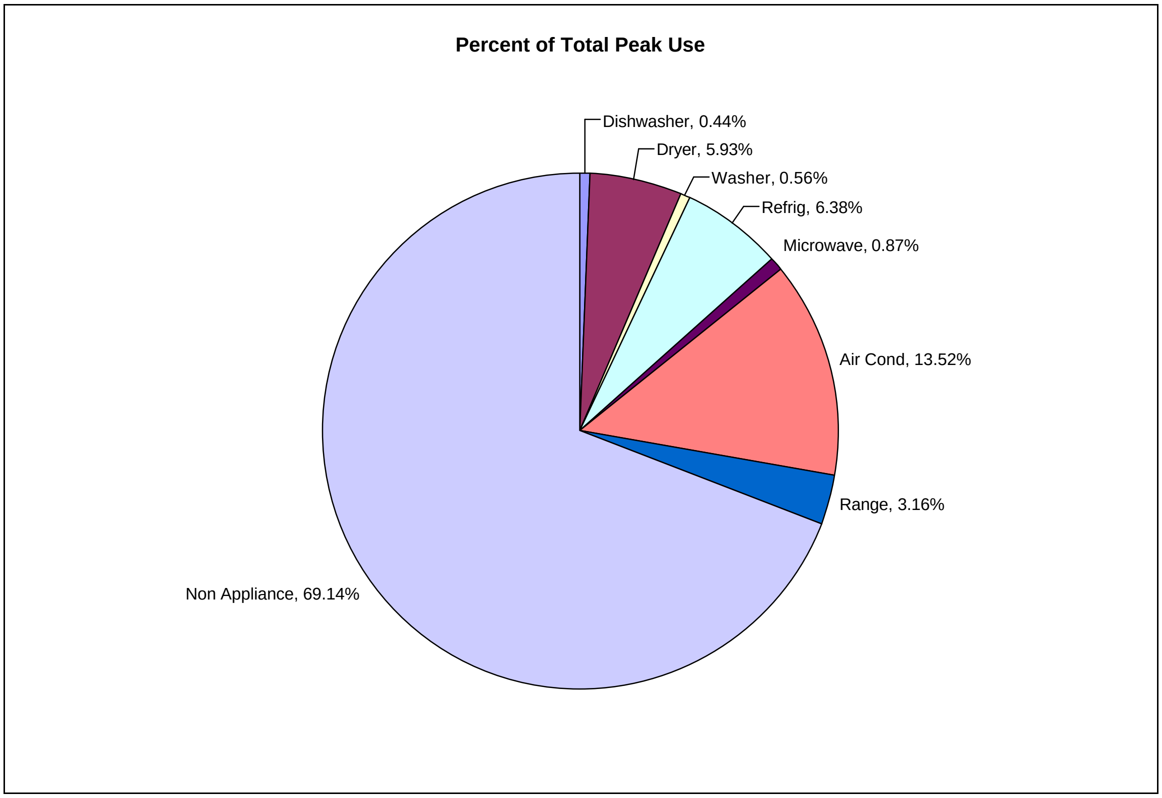


Graph 46

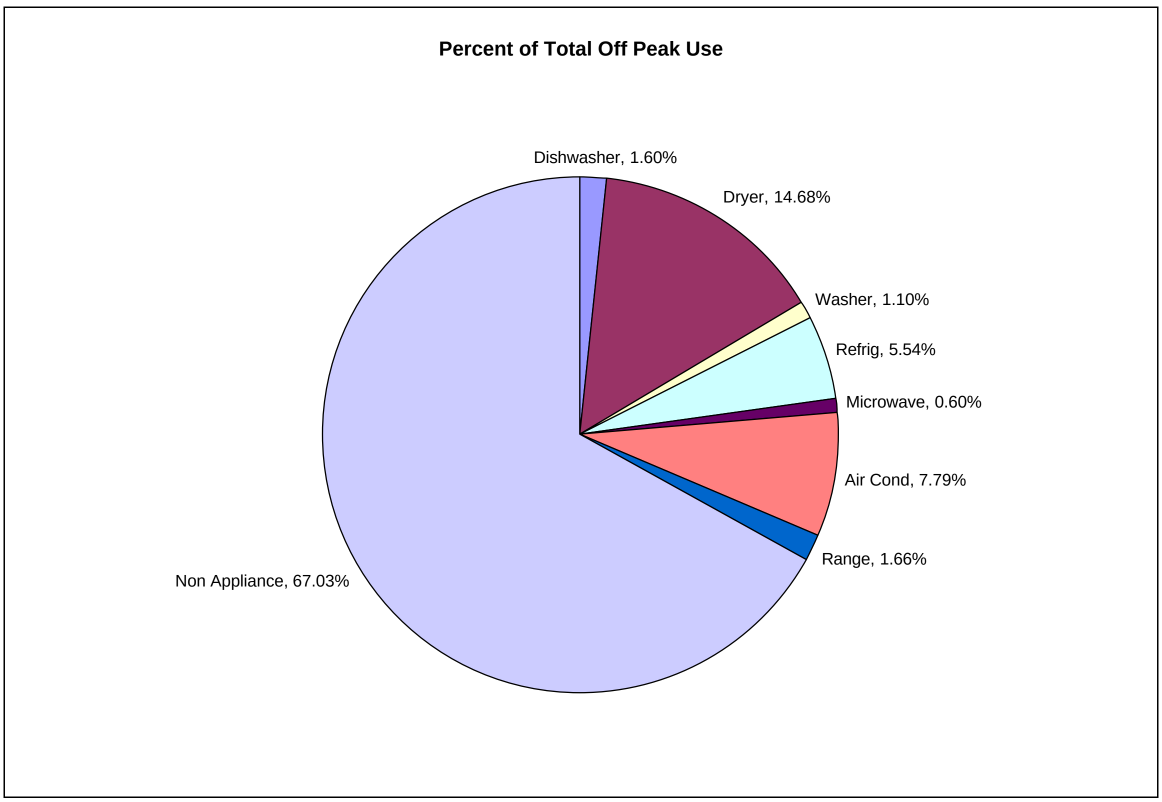


Graph 47

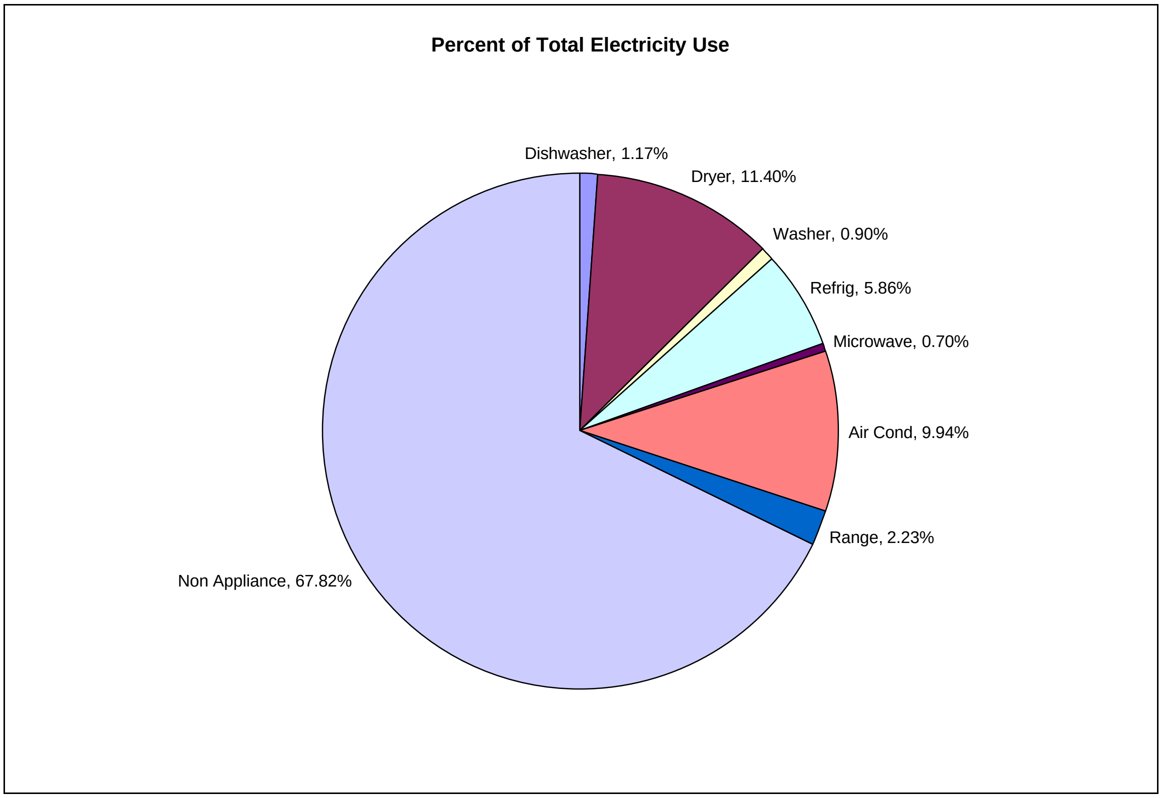
The three pie charts below (graphs 48-50) further breakdown the pie charts by specific measured appliance and other circuits illustrating the peak, off-peak, and total usage breakdown by appliance in the summarized home data.



Graph 48

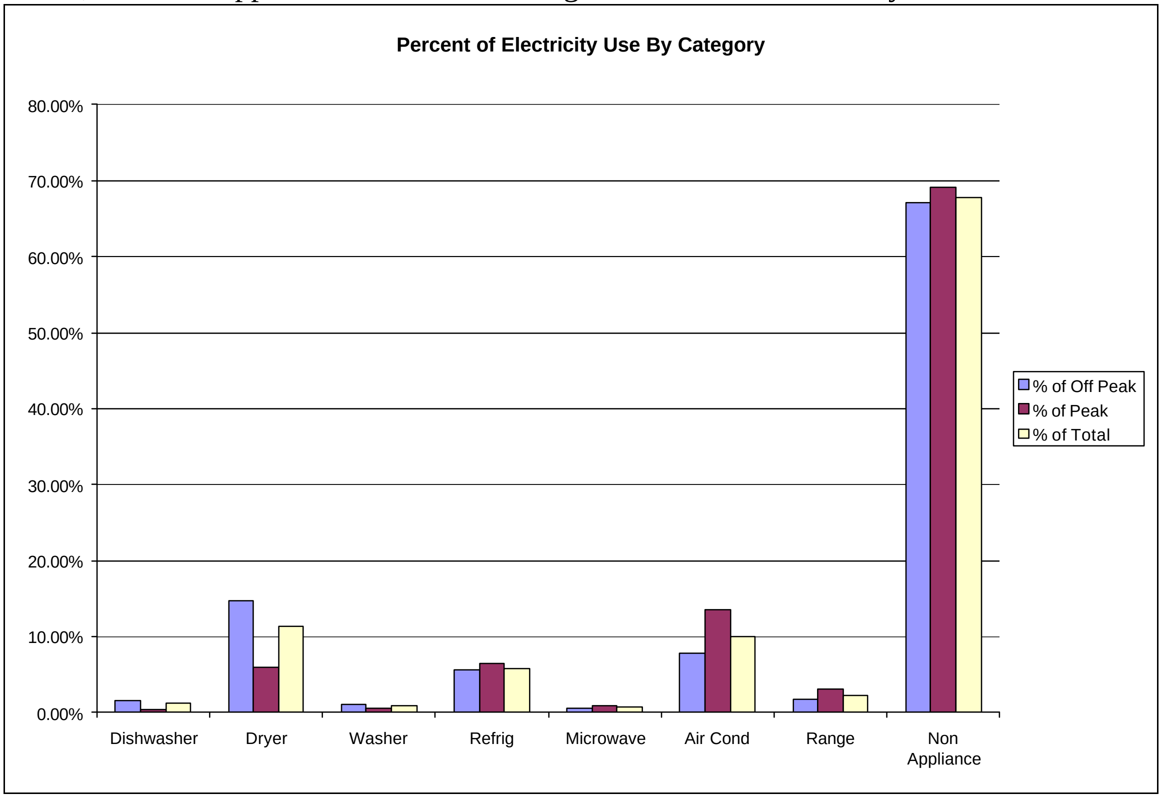


Graph 49



Graph 50

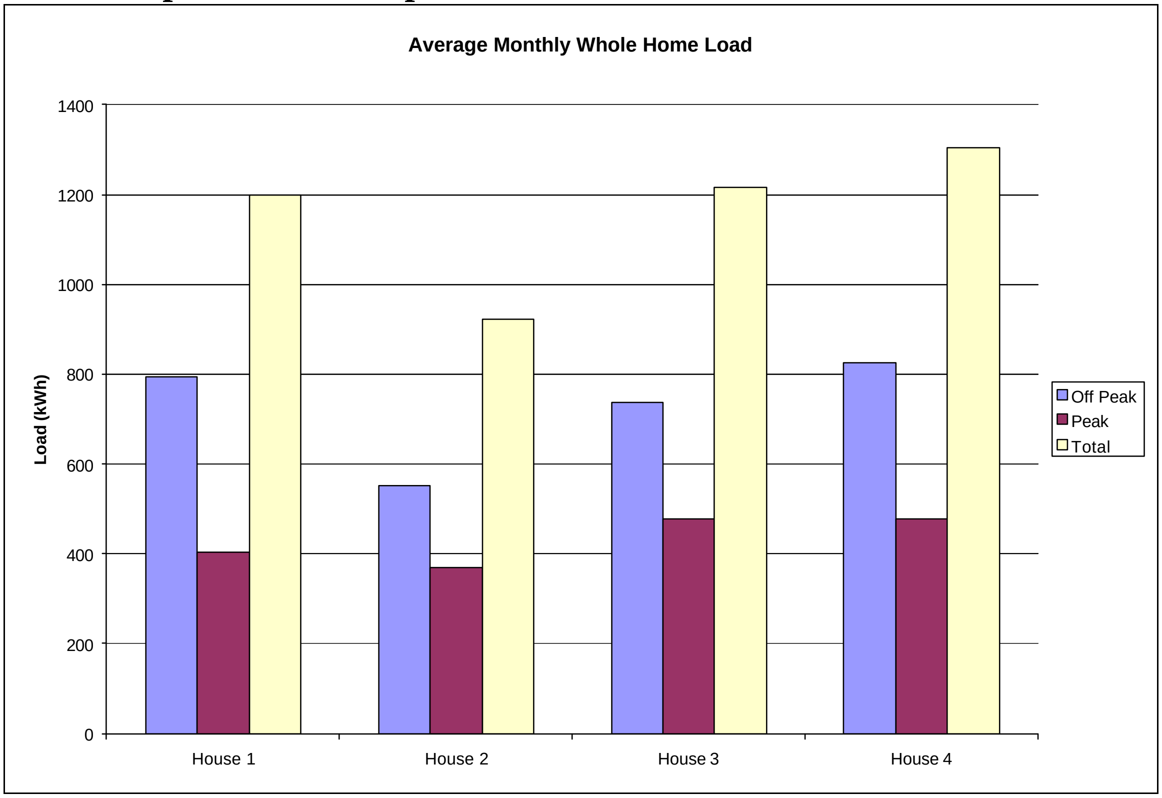
Chart #51, below, illustrates the summed usage breakdown in bar format. When combined with the various load curve graphs, this helps to identify where further gains may be possible. Note however, that each appliance has different usage characteristics that may alter initial conclusions.



Graph 51

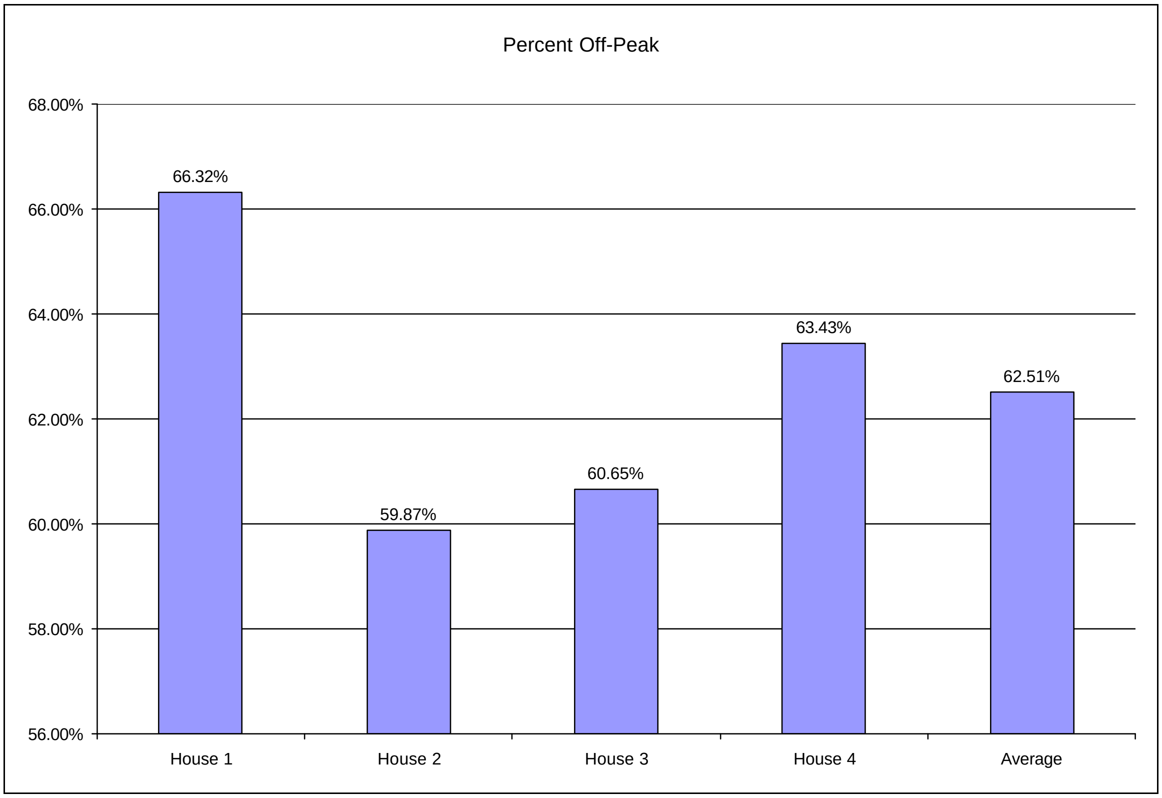
Data by home

Peak and off-peak TOU comparisons



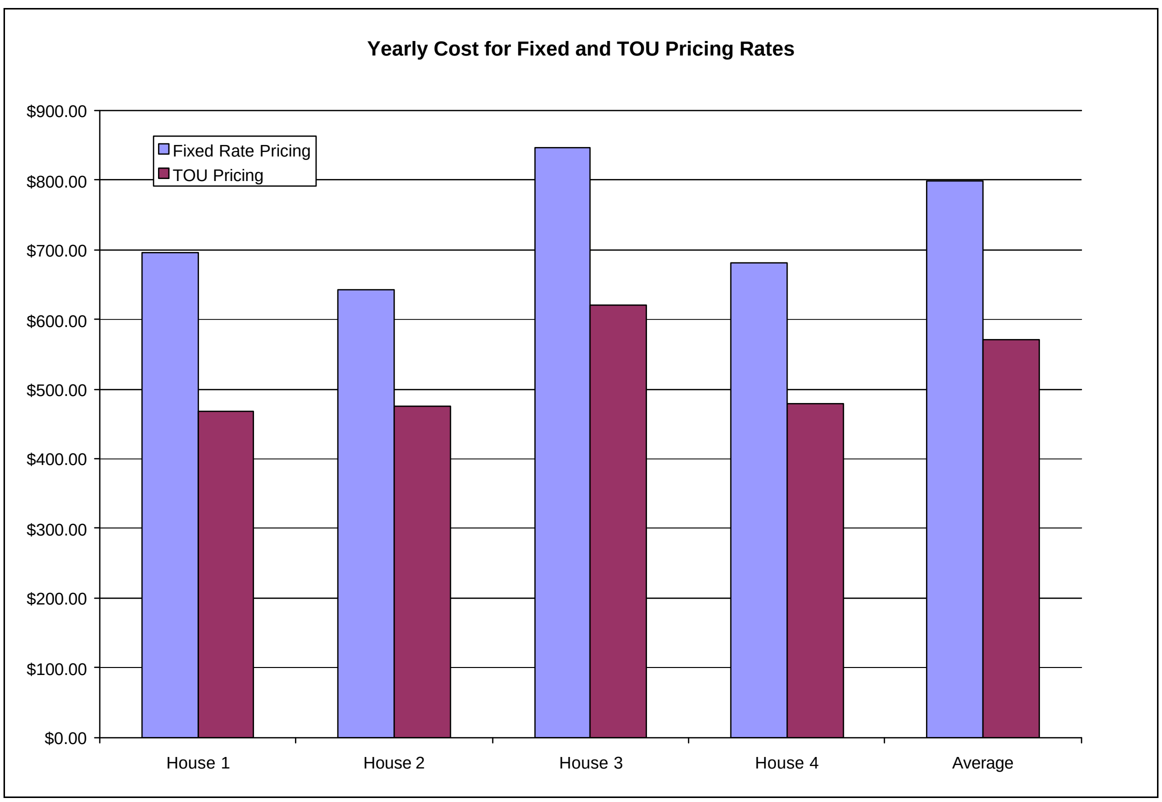
Graph 52

Graph 52 shows a side-by-side TOU comparison of the total electricity used during the average month for each house. Average was calculated by summing monthly use for each house and dividing by total number of months. Recall that house 2 is an energy efficient home. With lower HVAC use in home #2, there is less TOU movement possible and the non-HVAC loads are exaggerated in comparison, which may be significantly responsible for less contrast between peak and off-peak for that particular home.



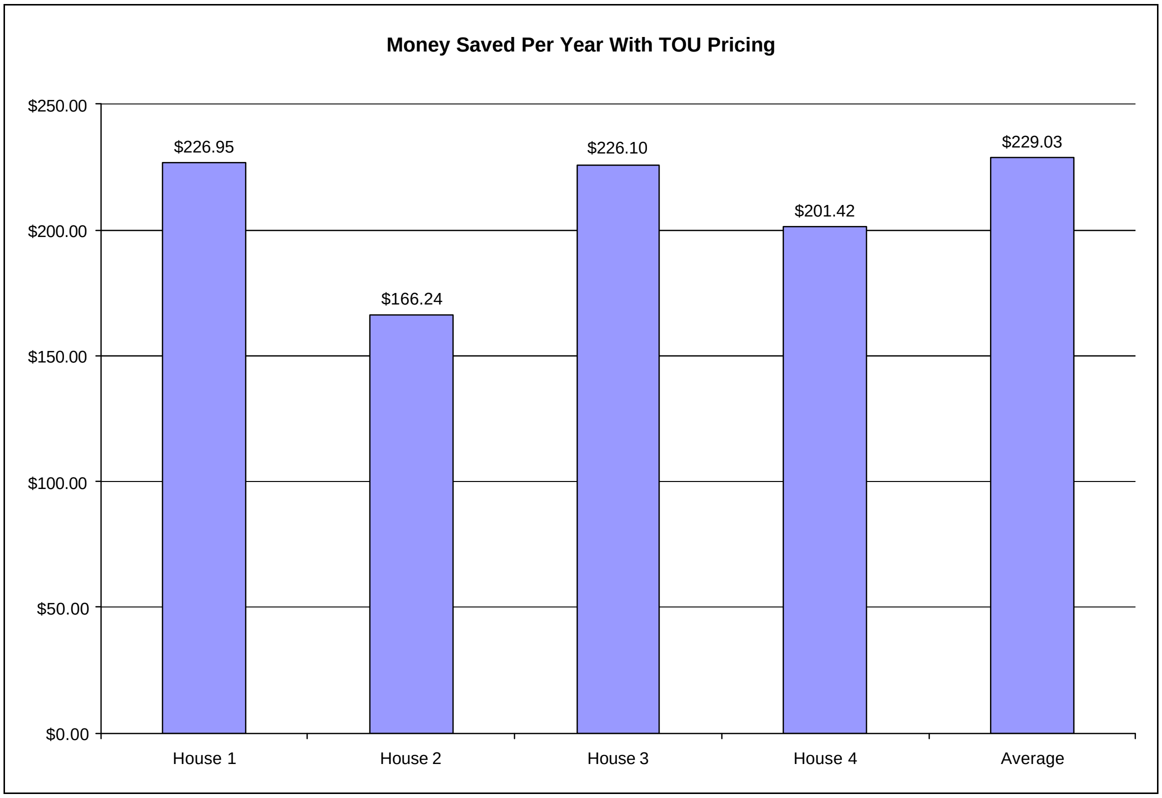
Graph 53

Percent off-peak is total electricity use that occurred at an off peak time over a one year period.

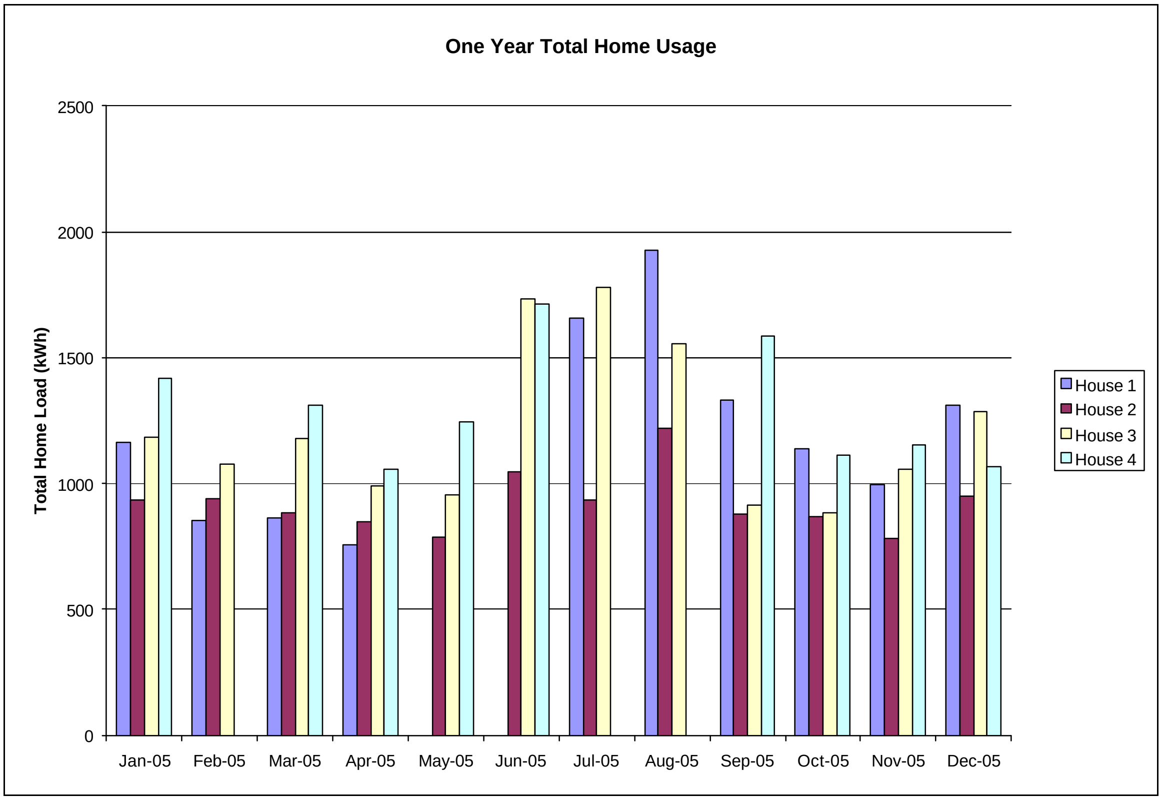


Graph 54

Graph 54 displays the approximate yearly cost for each house comparing what they paid on the TOU rate with what they would have paid on the applicable fixed rate tariff. Graph 55 shows the cost difference (fixed vs. TOU) for each home over a one year period.



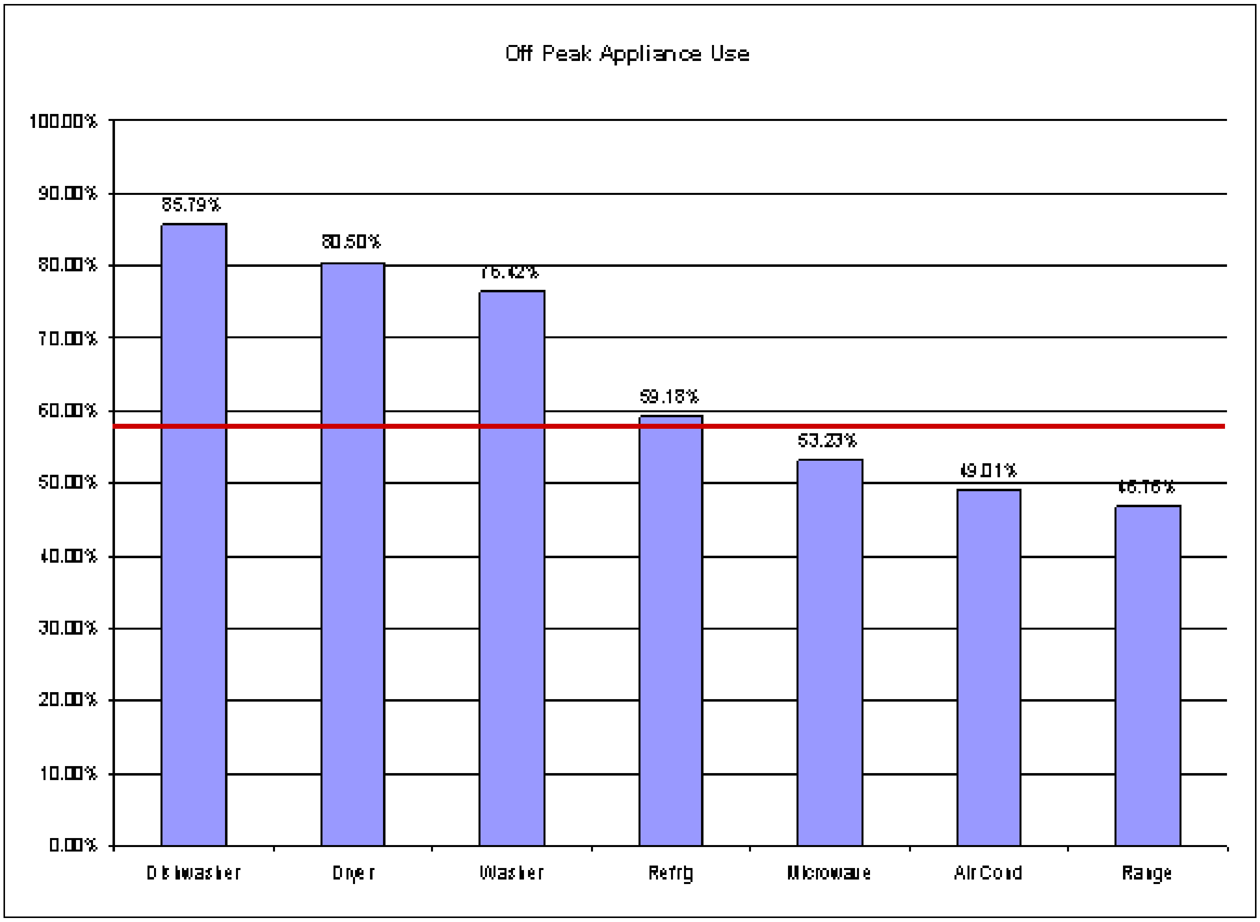
Graph 55



Graph 56

The total load on each house is compared by month in graph 56. (Note that where some data was missing, the affected months are not shown). Units are kWh.

Appliance specific data:

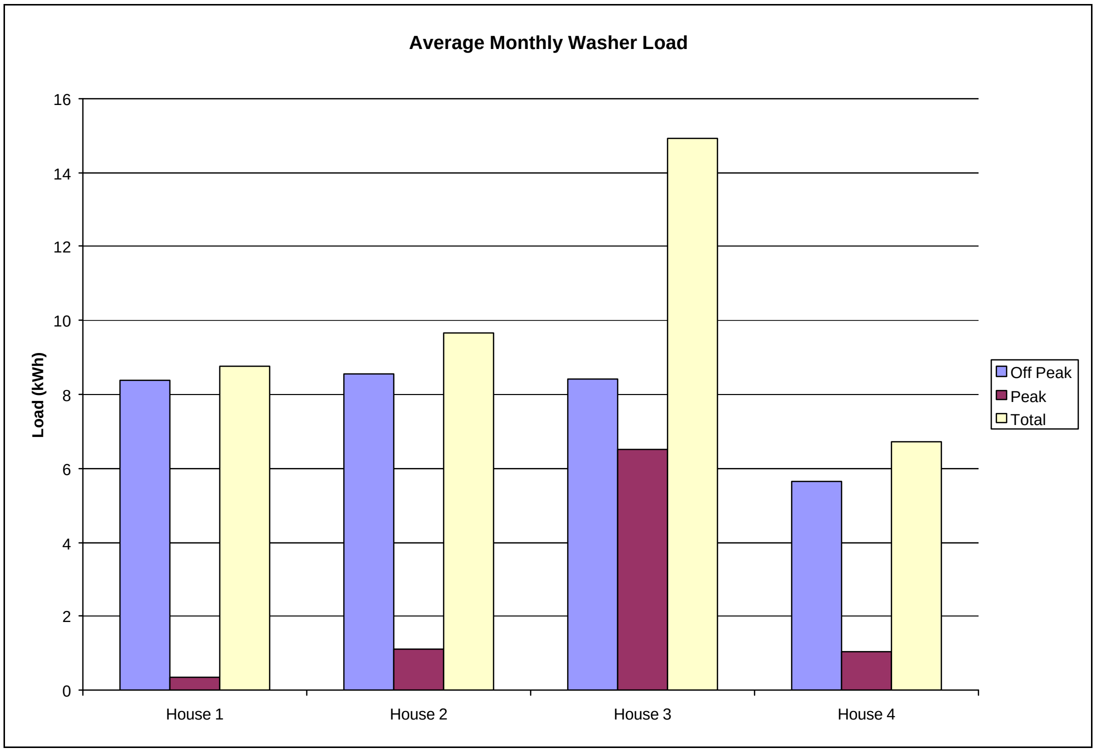


Graph 57

Graph 57 shows the percentage of energy each appliance used during the off-peak hours of the day. The graph is sorted left to right in order of off-peak percentage. An interesting observation is that for the AEP TOU rate used for this region, unless there is a holiday during the week (7 utility holidays observed per year), 70 hours are on peak and 98 hours are off-peak. In other words, 58.3% of the time is off-peak while 41.7% is on peak. The red line in graph 57 helps determine which appliances were used more or less than the actual percentage of off-peak time in a typical week.

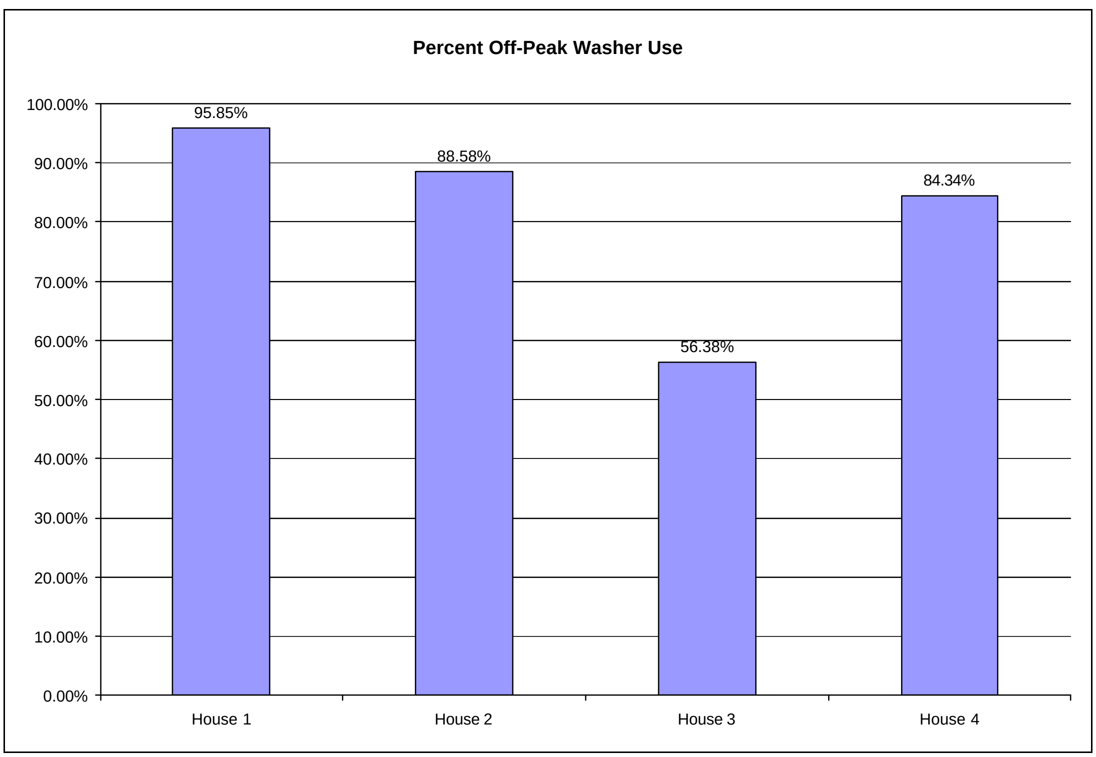
In the graphs that follow we can see, for each appliance, the use and savings associated with TOU pricing combined with their consumer usage patterns, compared by house.

Washer

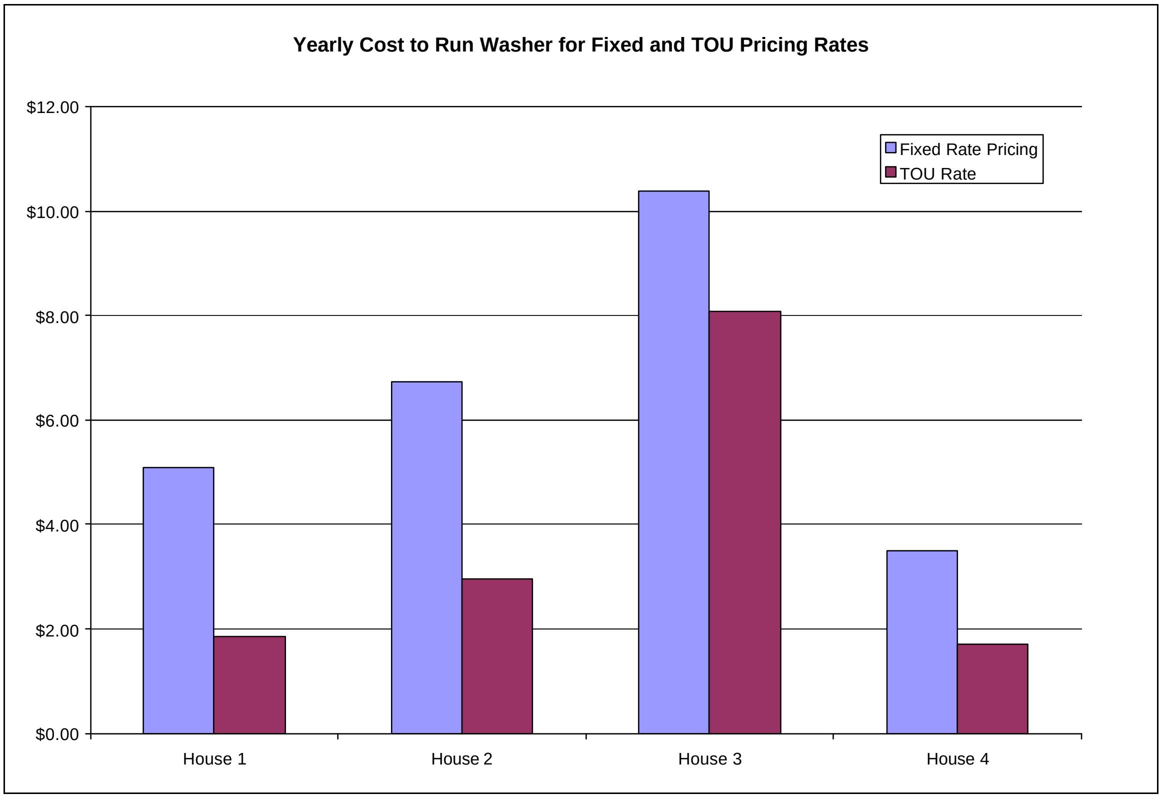


Graph 58

Total load from Jan to Dec 2005 in kWh.

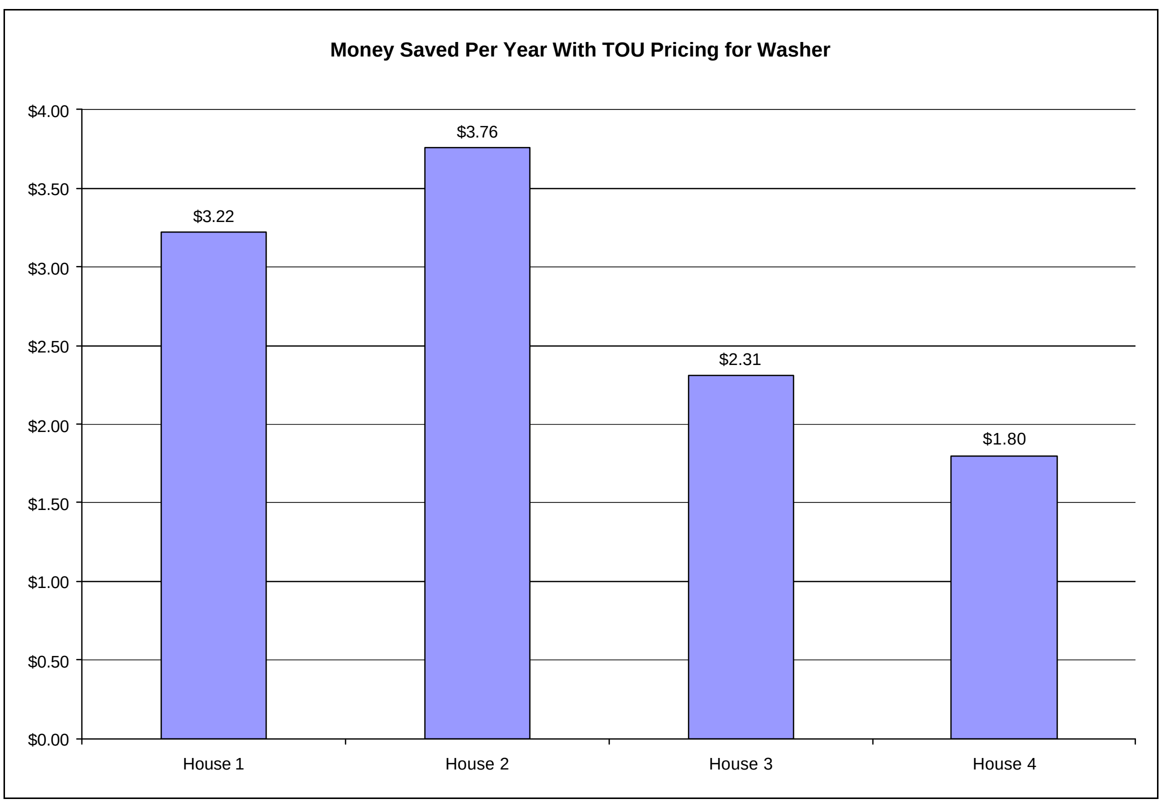


Graph 59



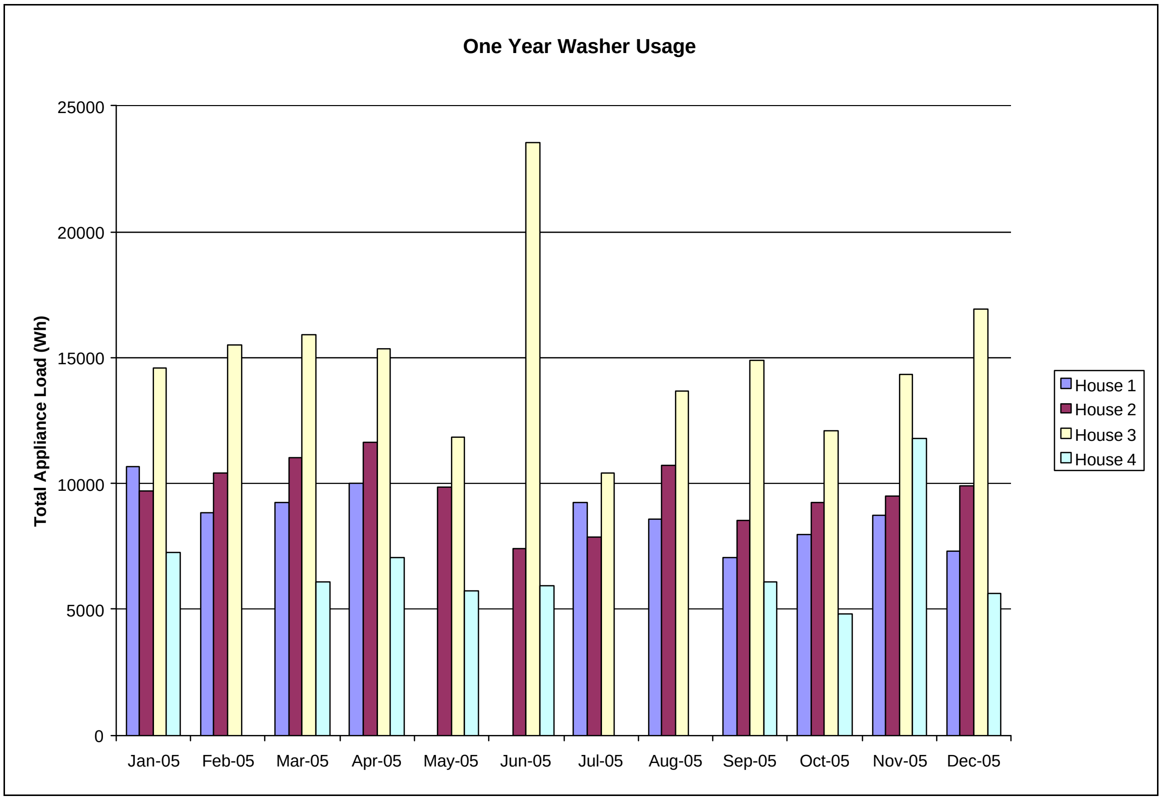
Graph 60

Cost using current local AEP TOU tariff (AEP Michigan tariff 016).



Graph 61

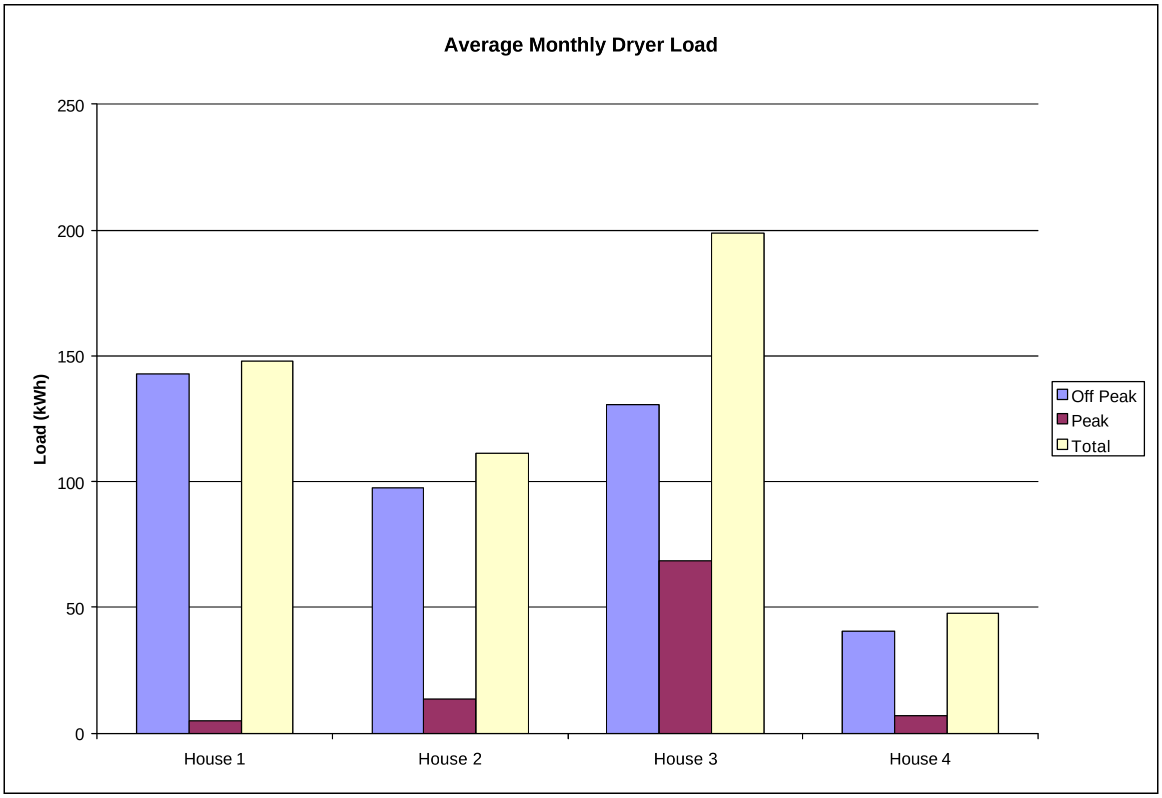
Cost using current local AEP TOU tariff (AEP Michigan tariff 016).



Graph 62

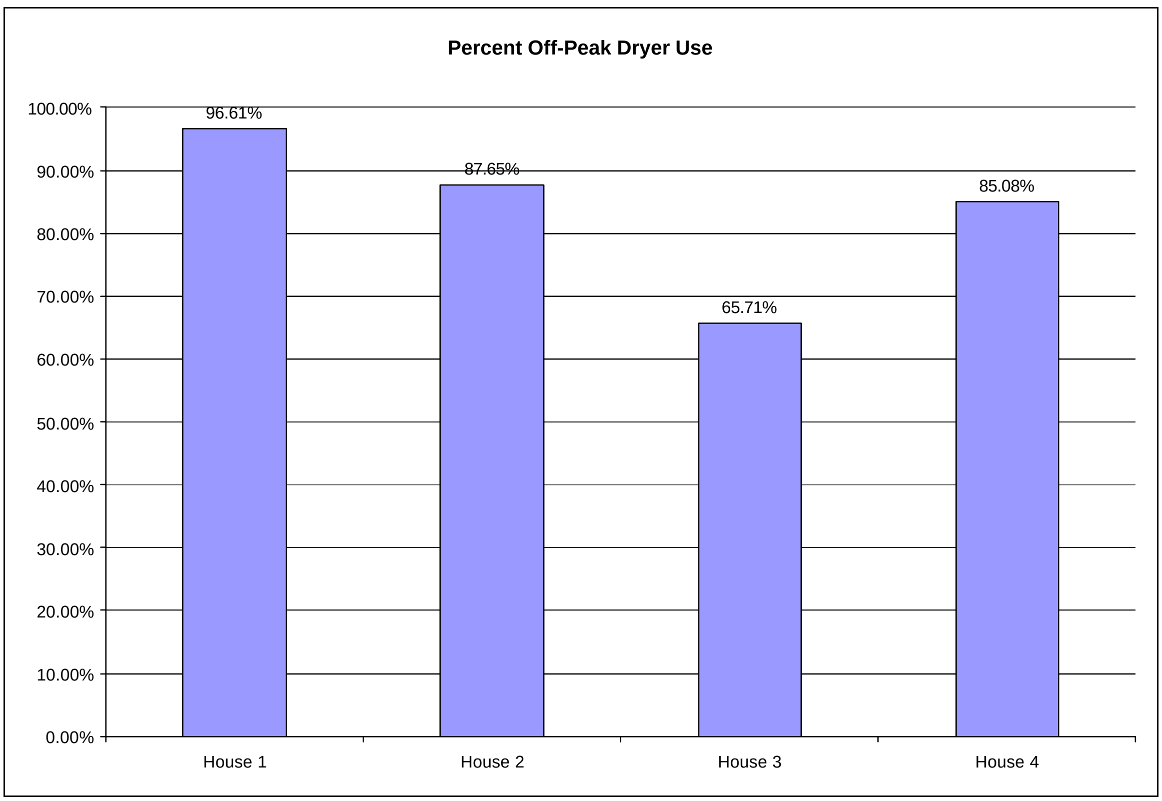
Total load comparison by house by month.

Dryer

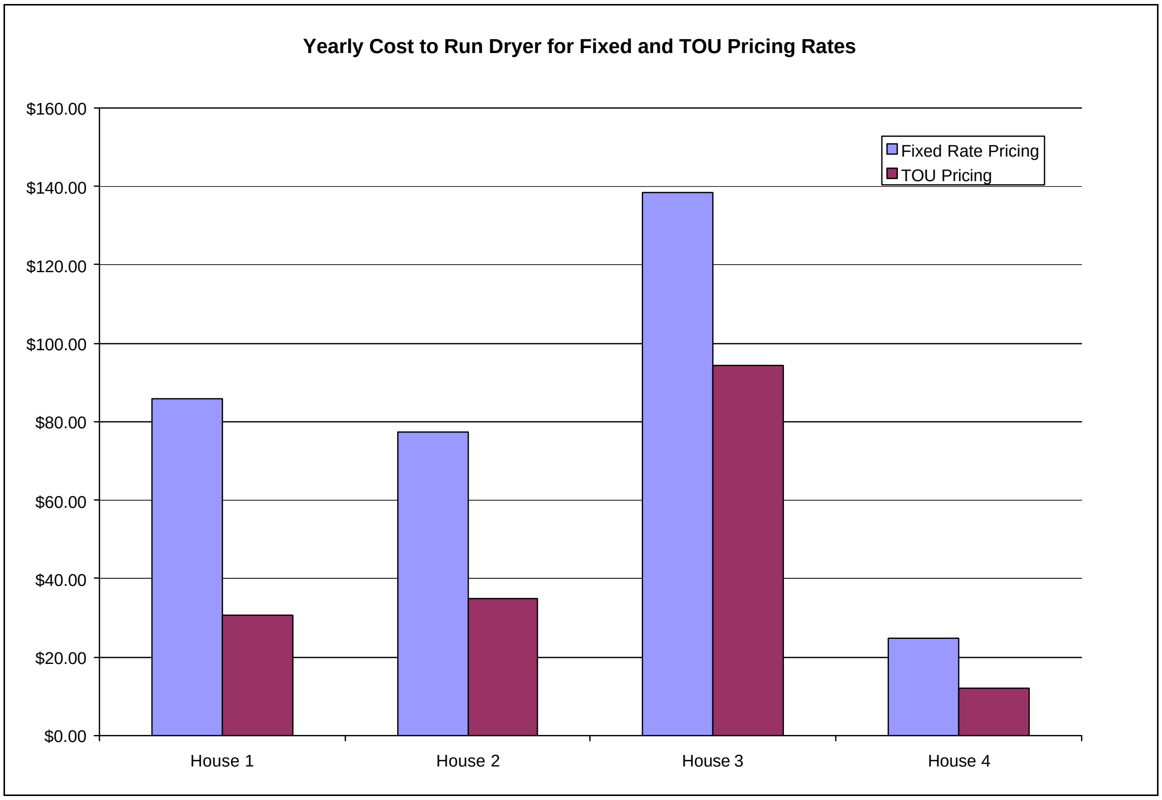


Graph 63

Total load from Jan to Dec 2005 in kWh.

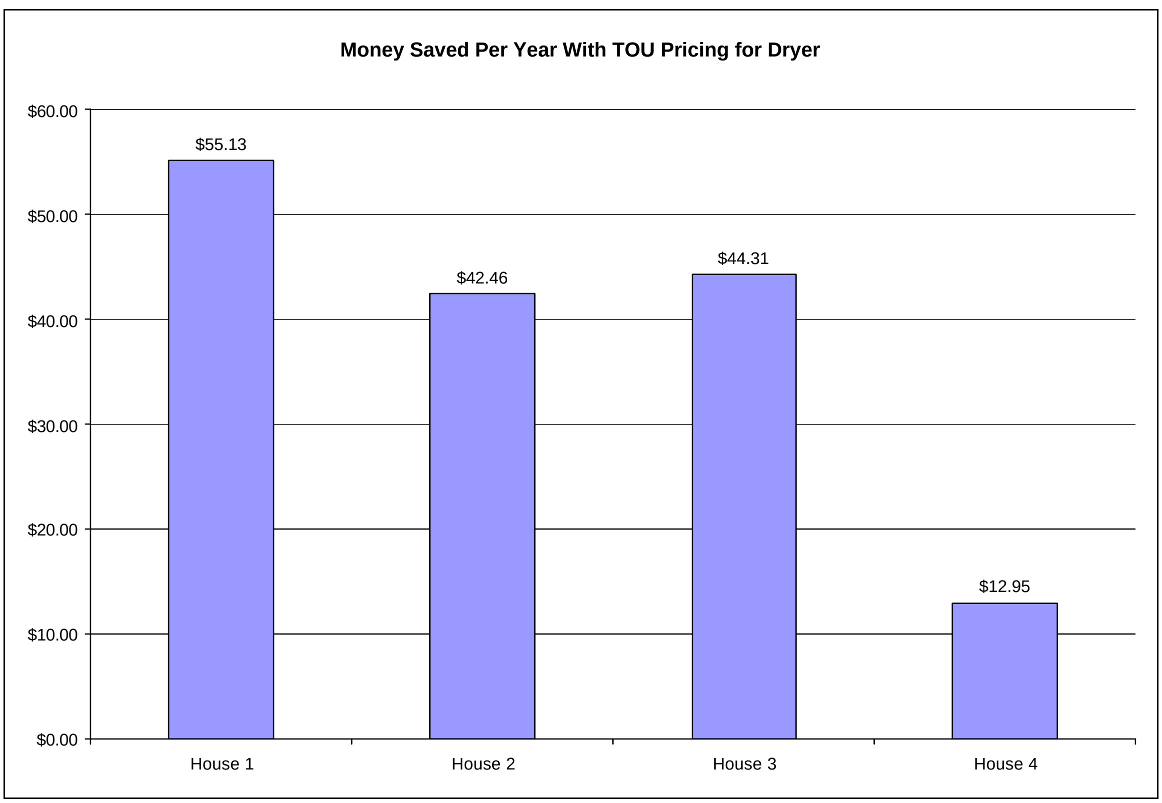


Graph 64



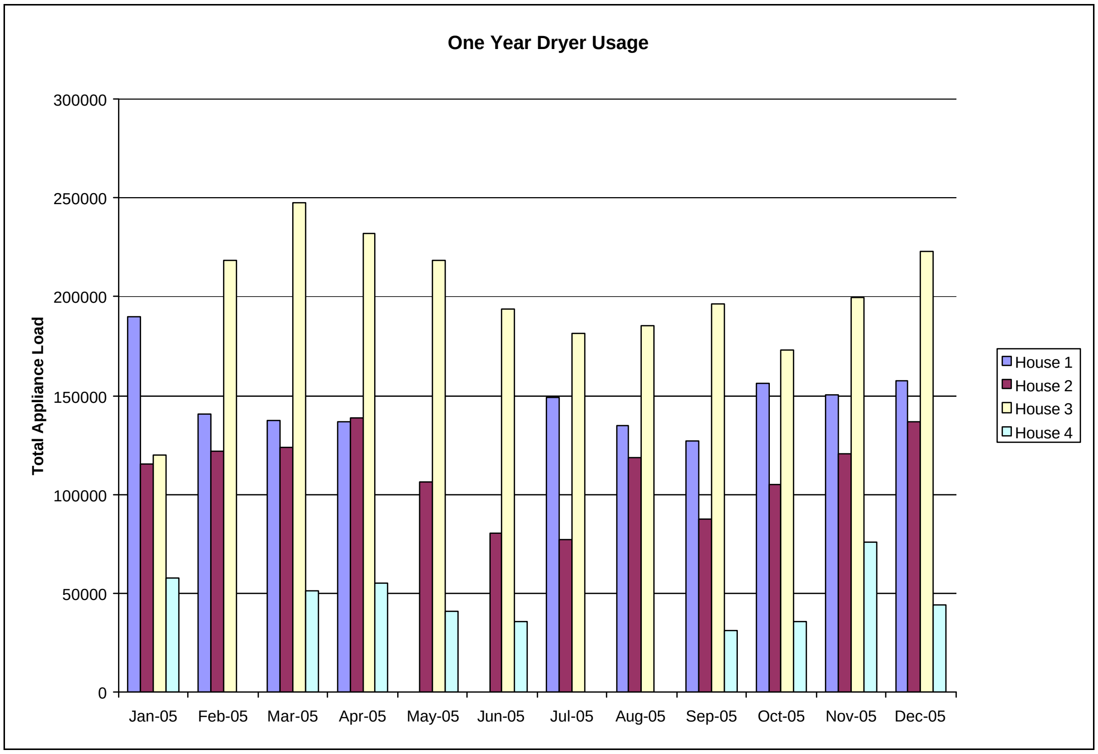
Graph 65

Cost using current local AEP TOU tariff (AEP Michigan tariff 016).



Graph 66

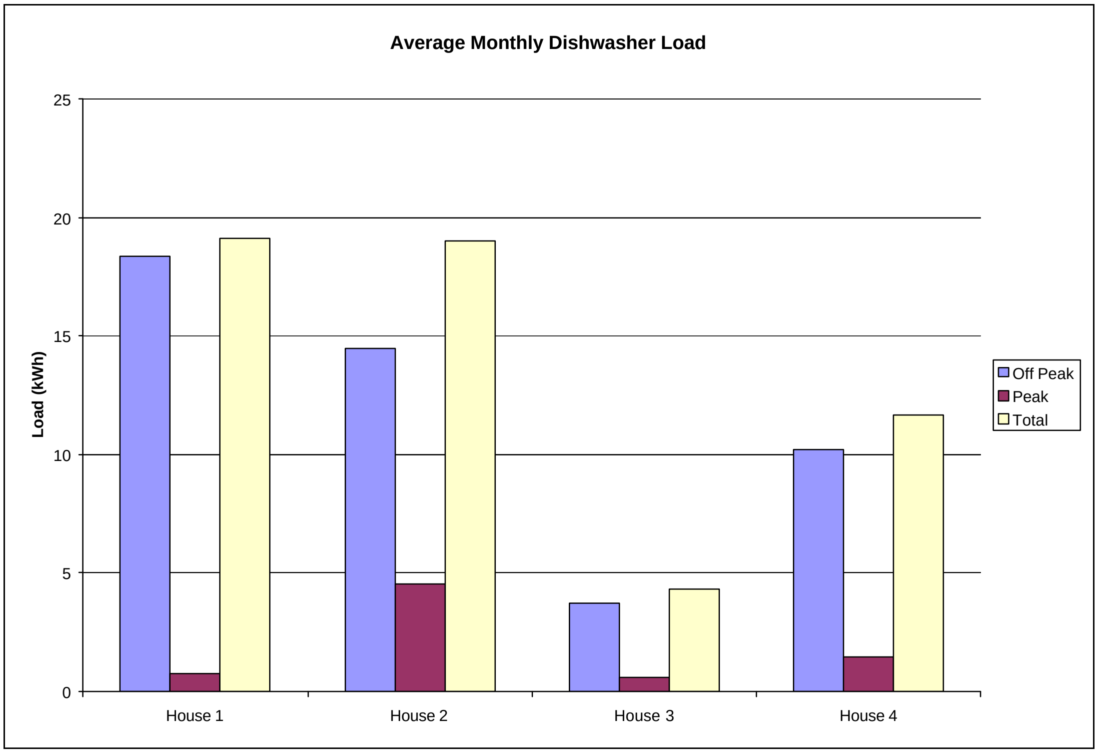
Cost using current local AEP TOU tariff (AEP Michigan tariff 016).



Graph 67

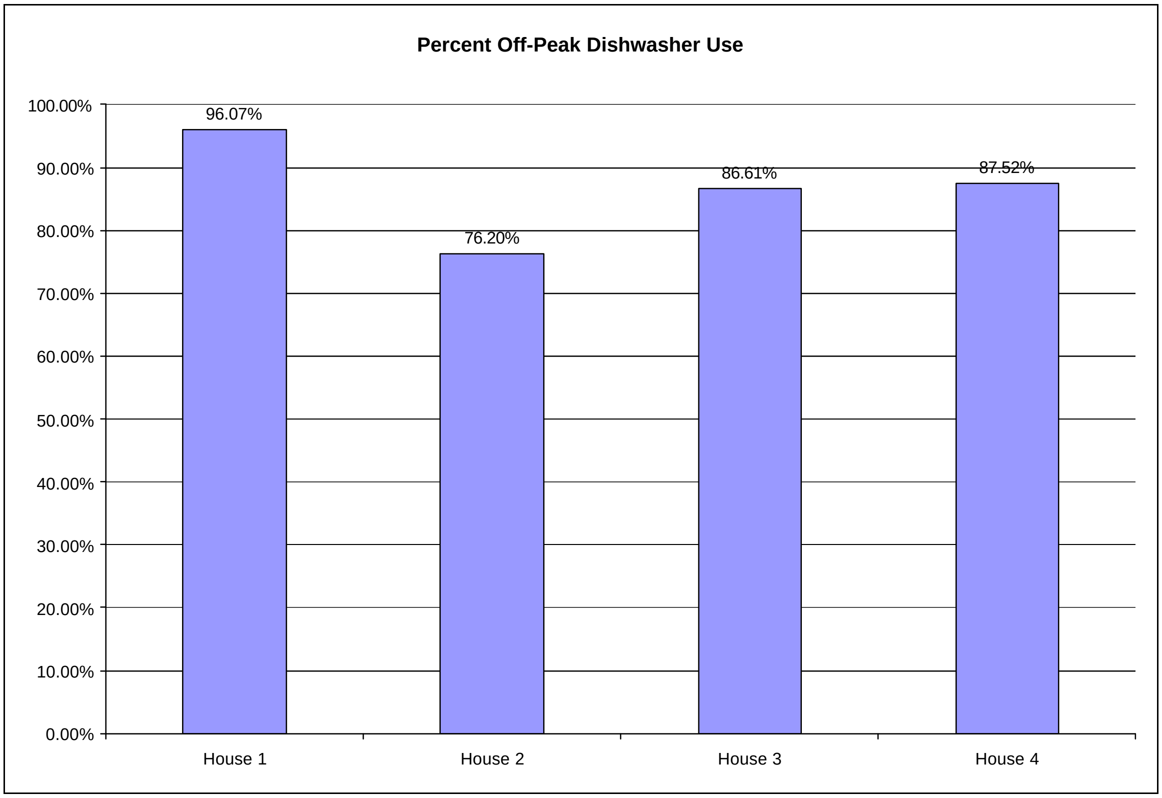
Total load comparison by house by month.

Dishwasher

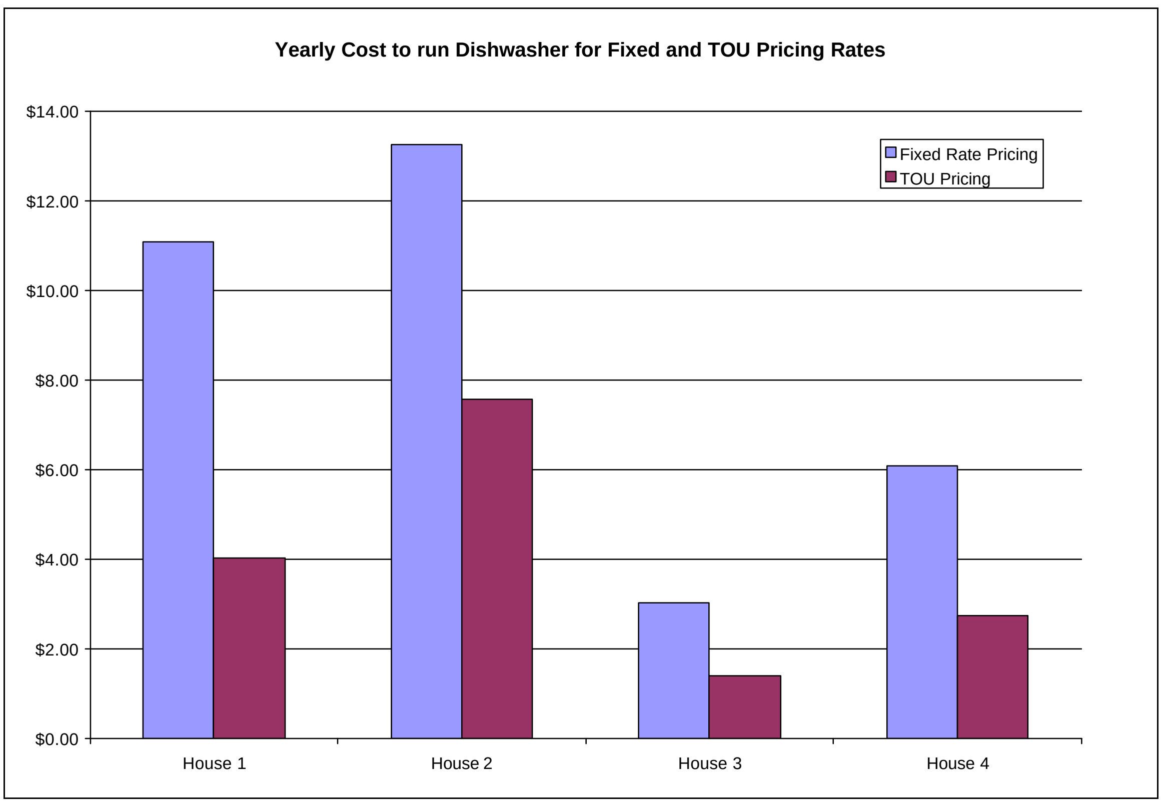


Graph 68

Total load from Jan to Dec 2005 in kWh.

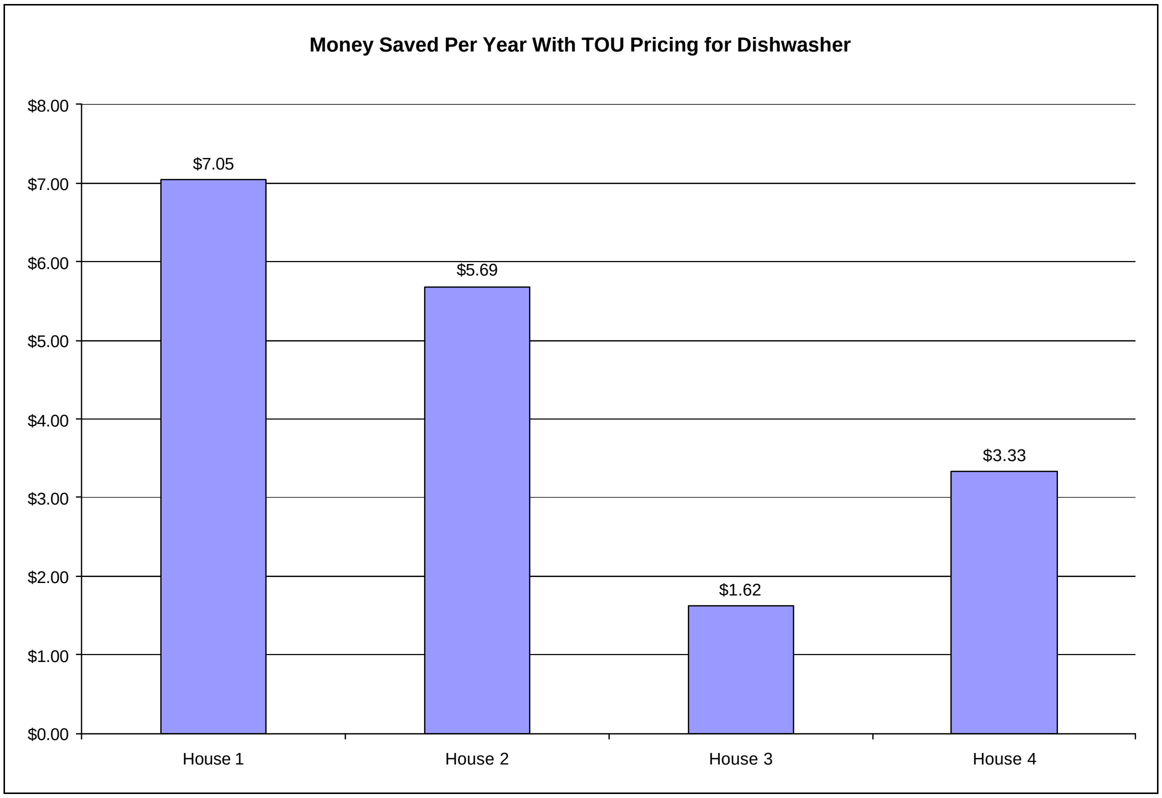


Graph 69



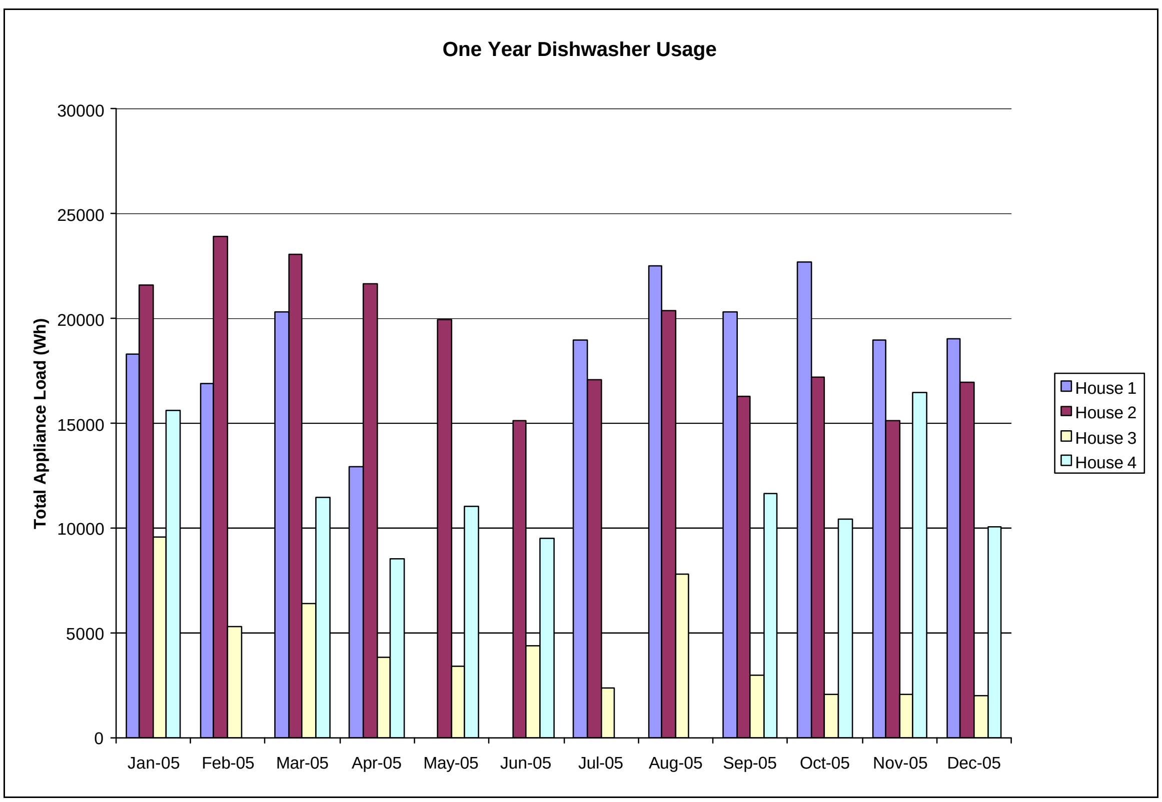
Graph 70

Cost using current local AEP TOU tariff (AEP Michigan tariff 016).



Graph 71

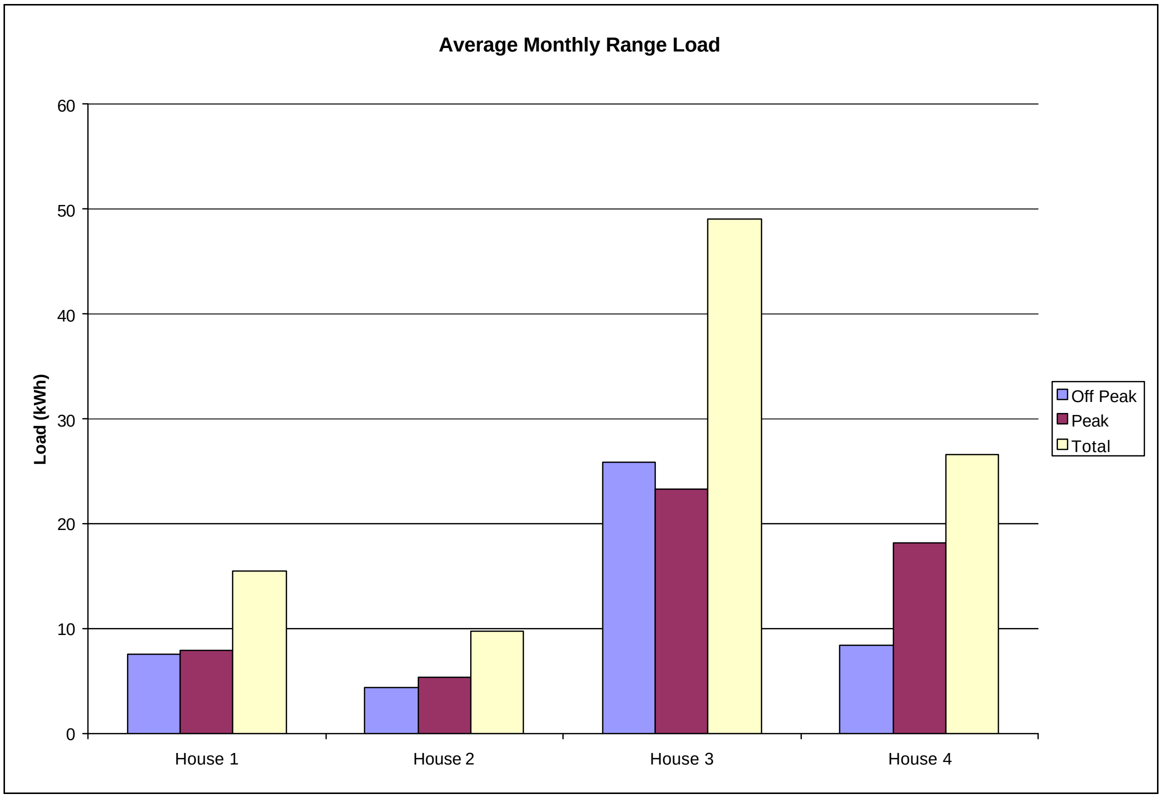
Cost using current local AEP TOU tariff (AEP Michigan tariff 016).



Graph 72

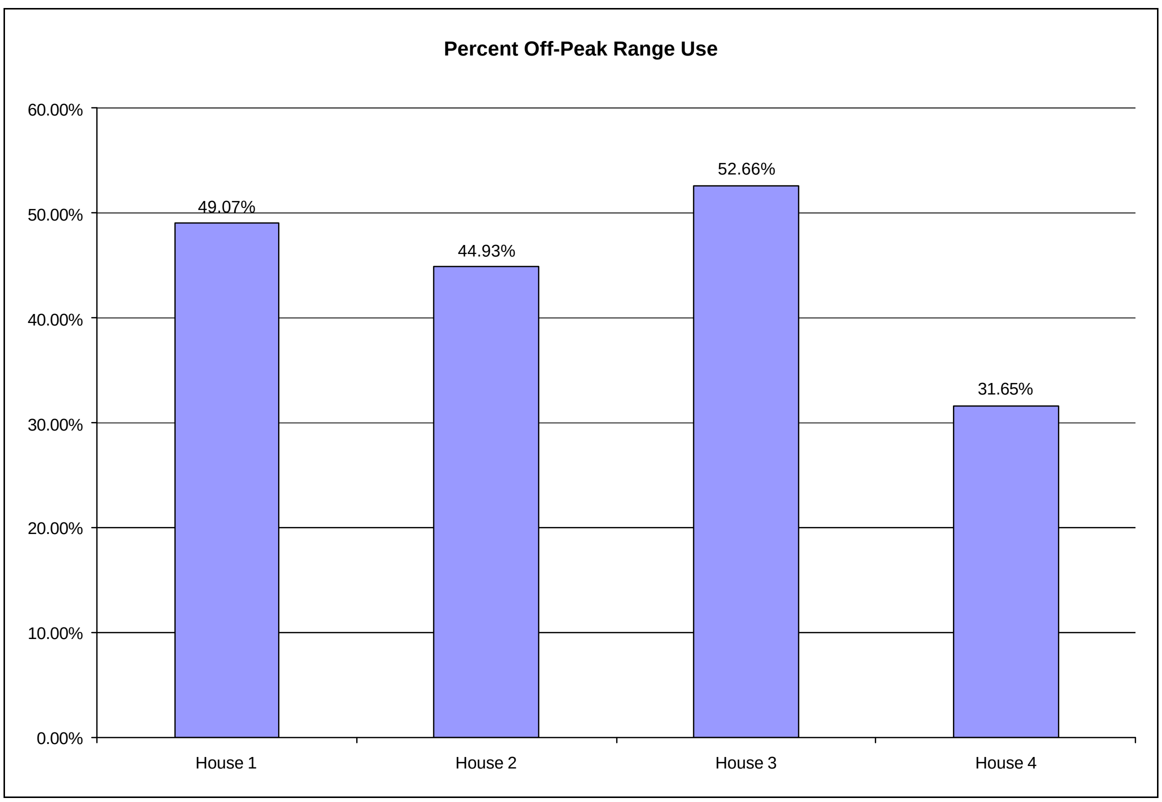
Total load comparison by house by month.

Range

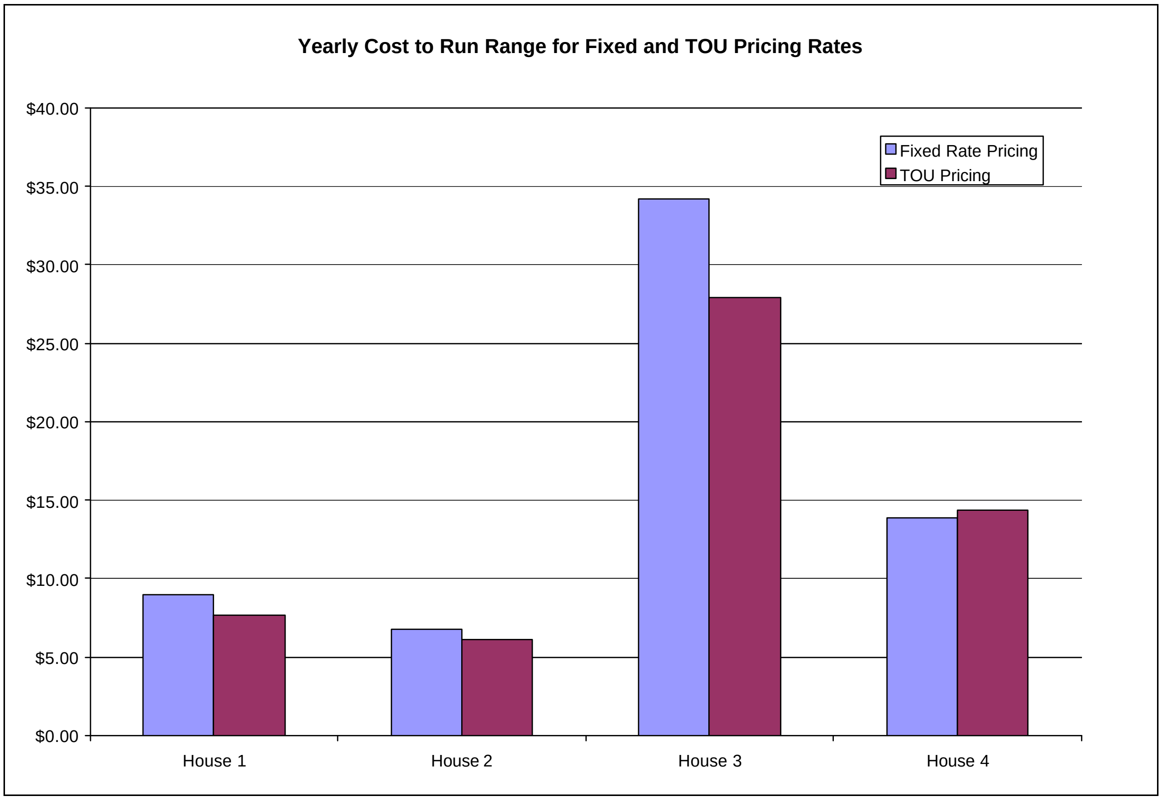


Graph 73

Total load from Jan to Dec 2005 in kWh.

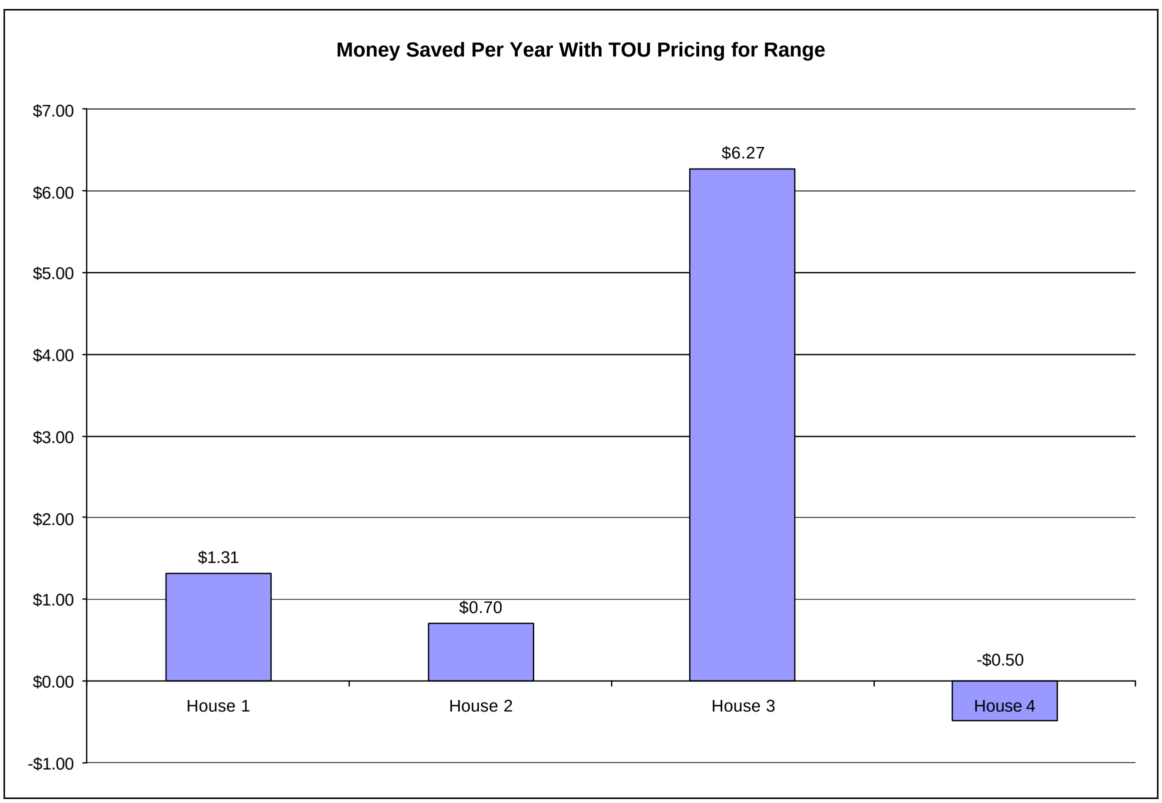


Graph 74



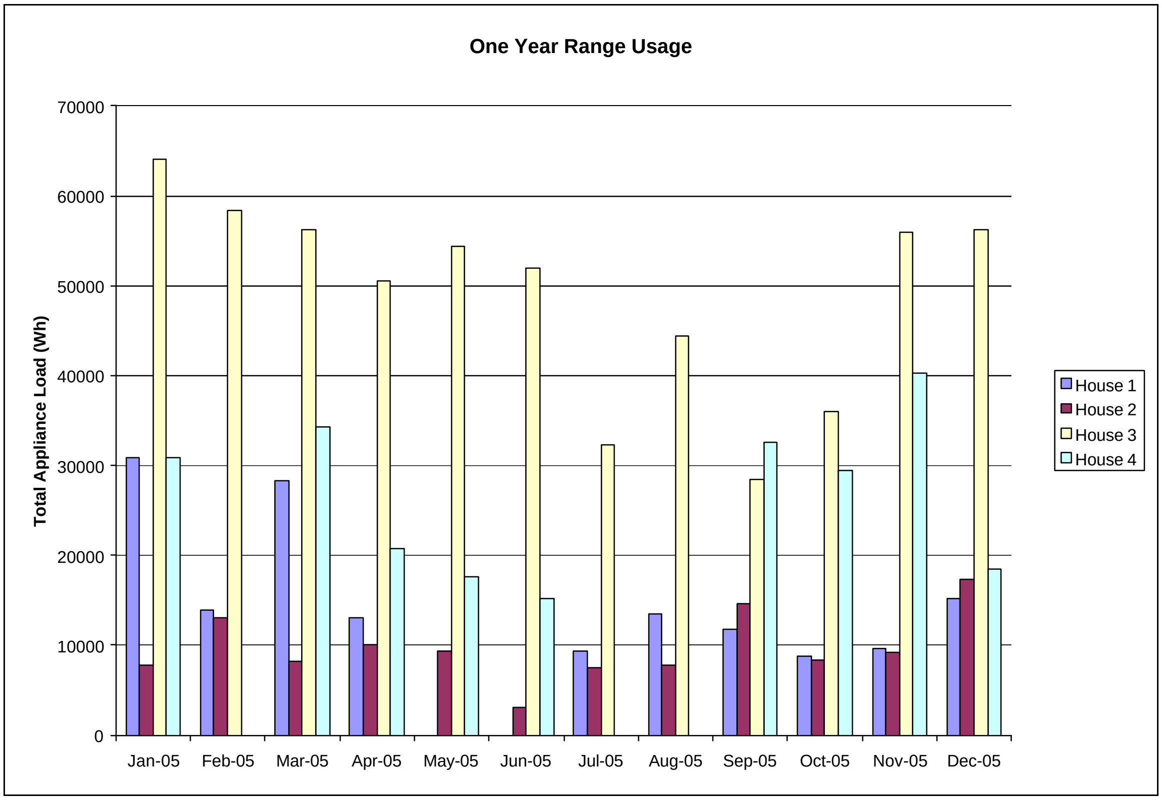
Graph 75

Cost using current local AEP TOU tariff (AEP Michigan tariff 016).



Graph 76

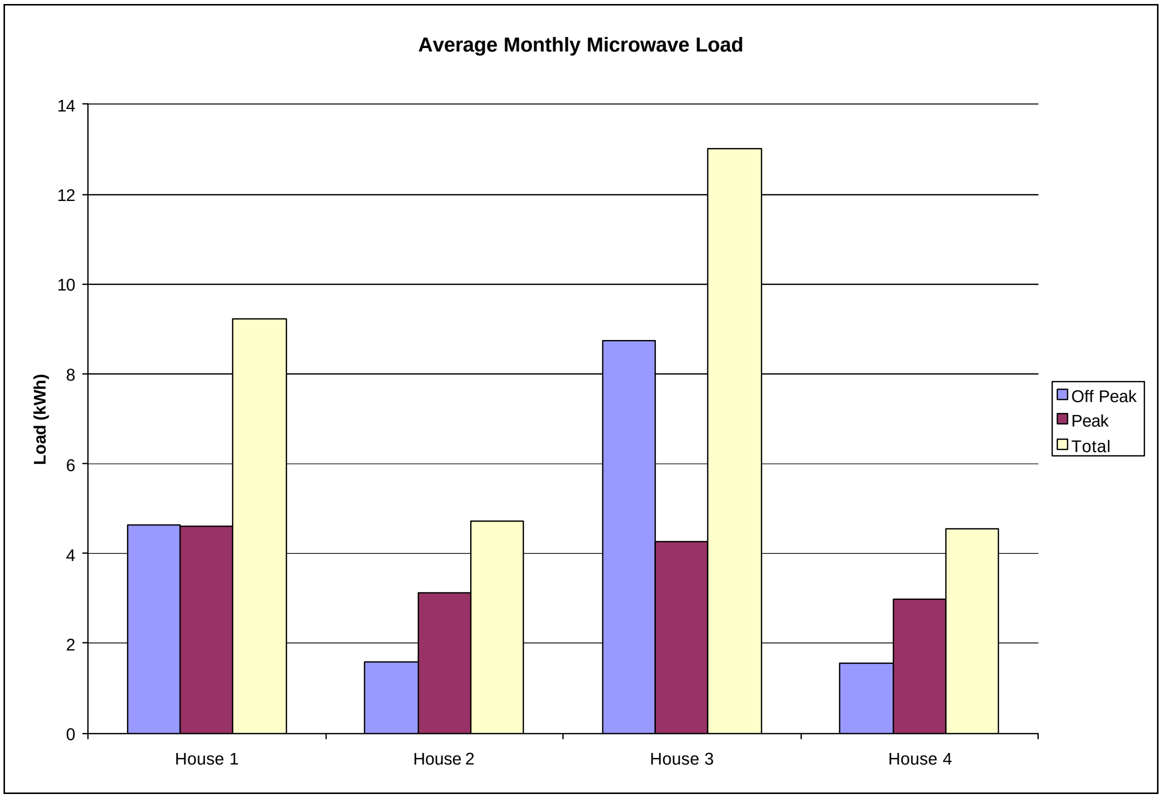
Cost using current local AEP TOU tariff (AEP Michigan tariff 016).



Graph 77

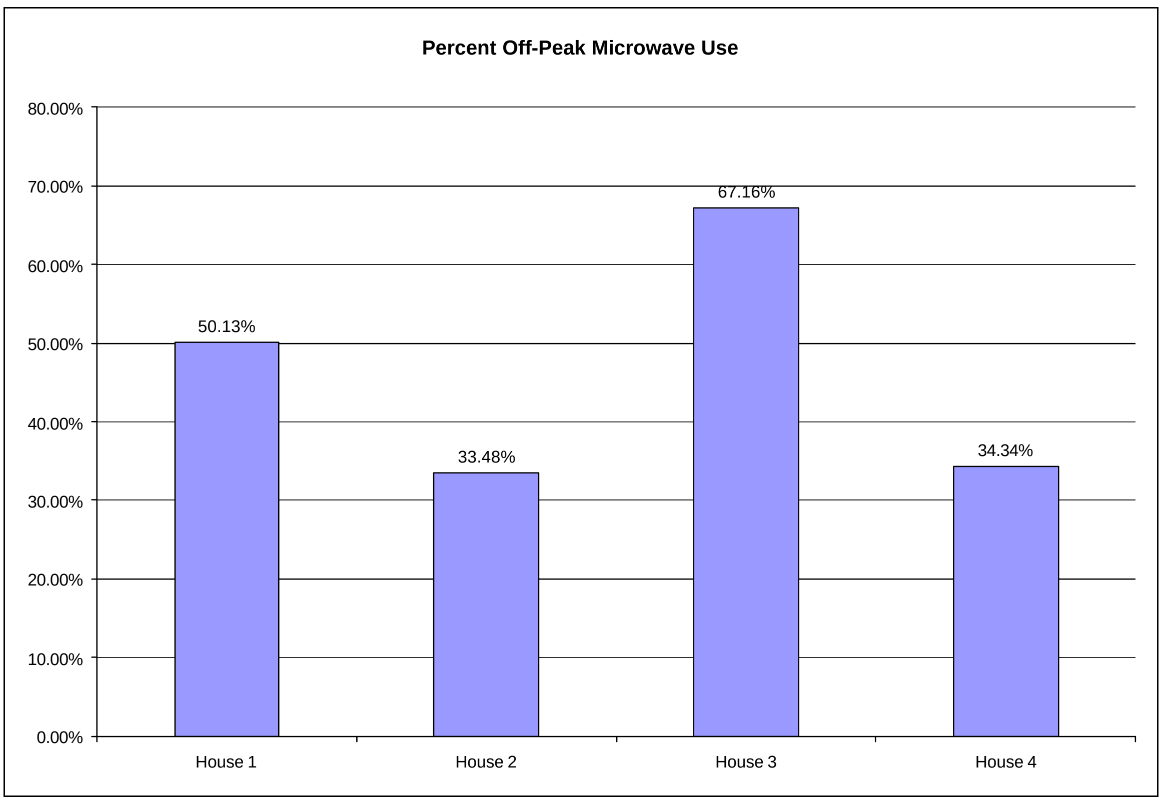
Total load comparison by house by month.

Microwave

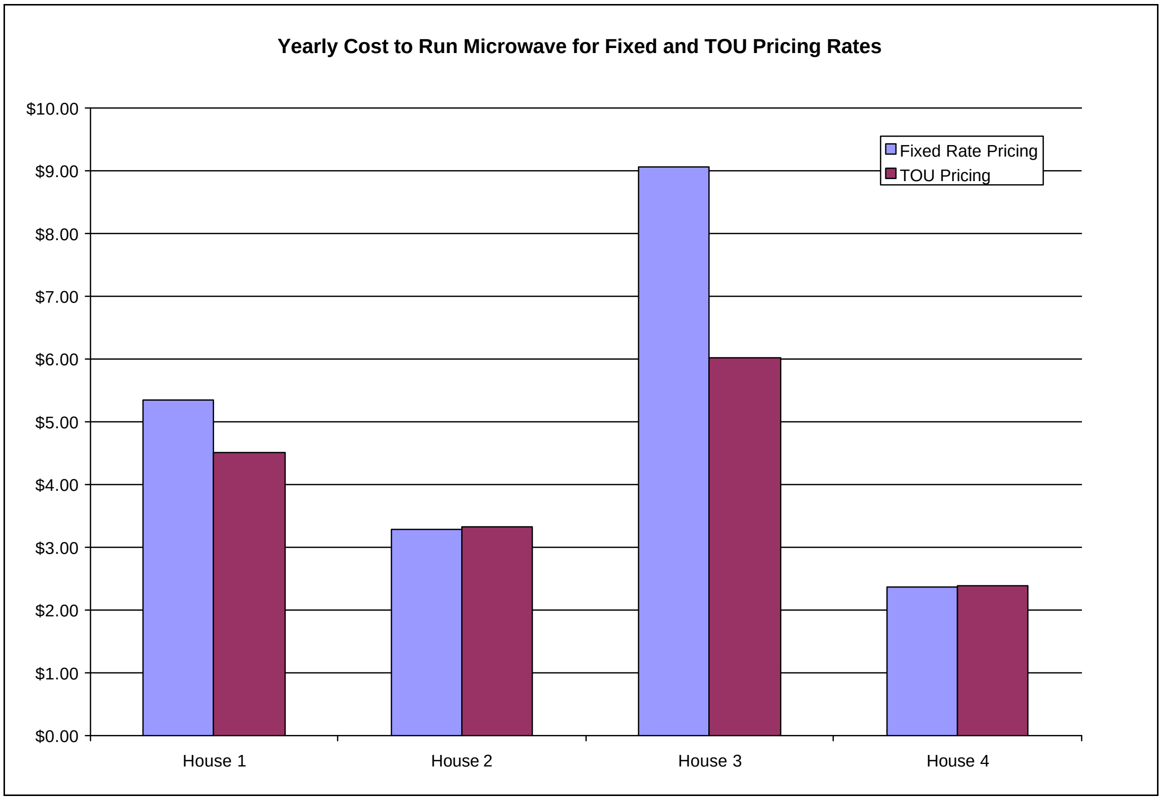


Graph 78

Total load from Jan to Dec 2005 in kWh.

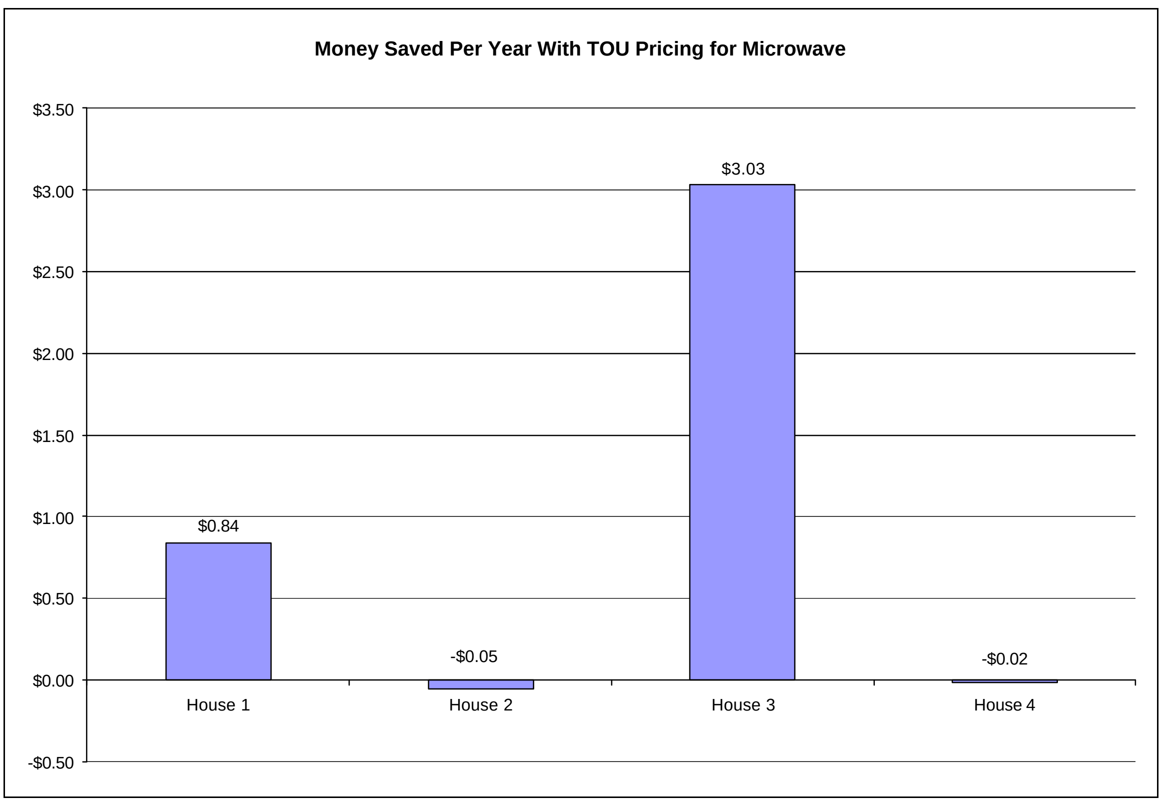


Graph 79



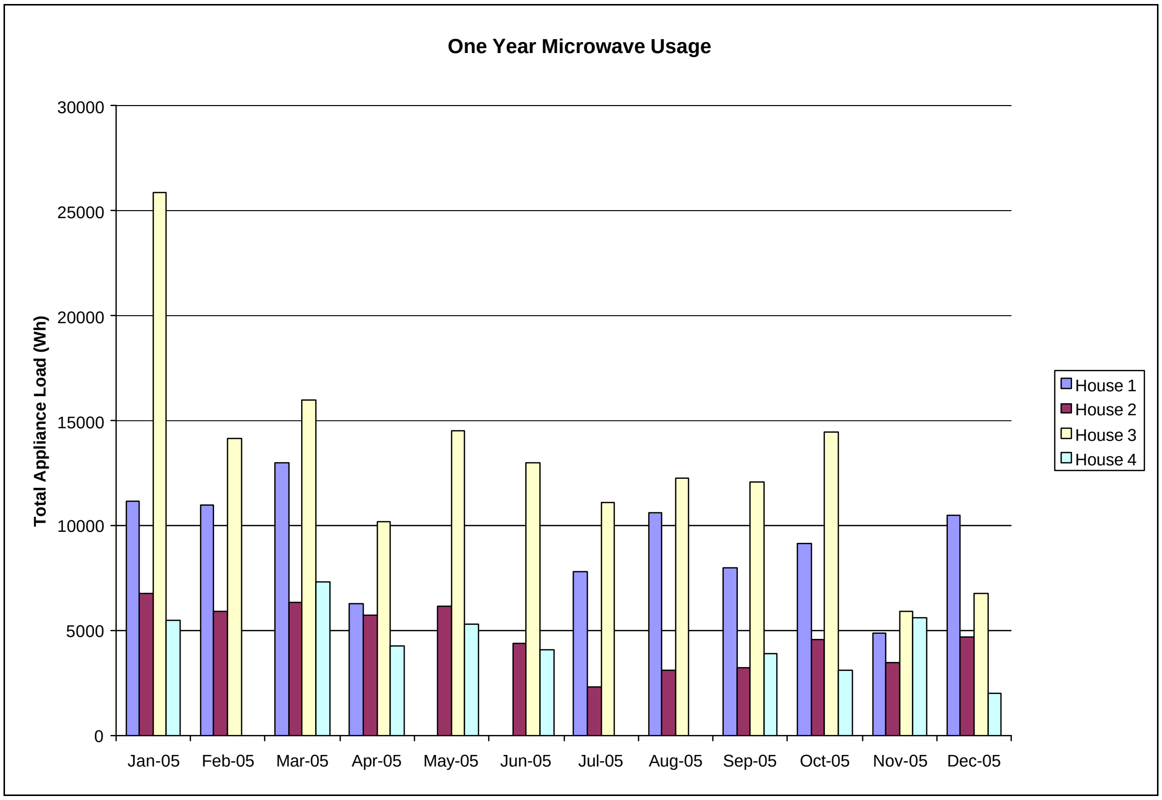
Graph 80

Cost using current local AEP TOU tariff (AEP Michigan tariff 016).



Graph 81

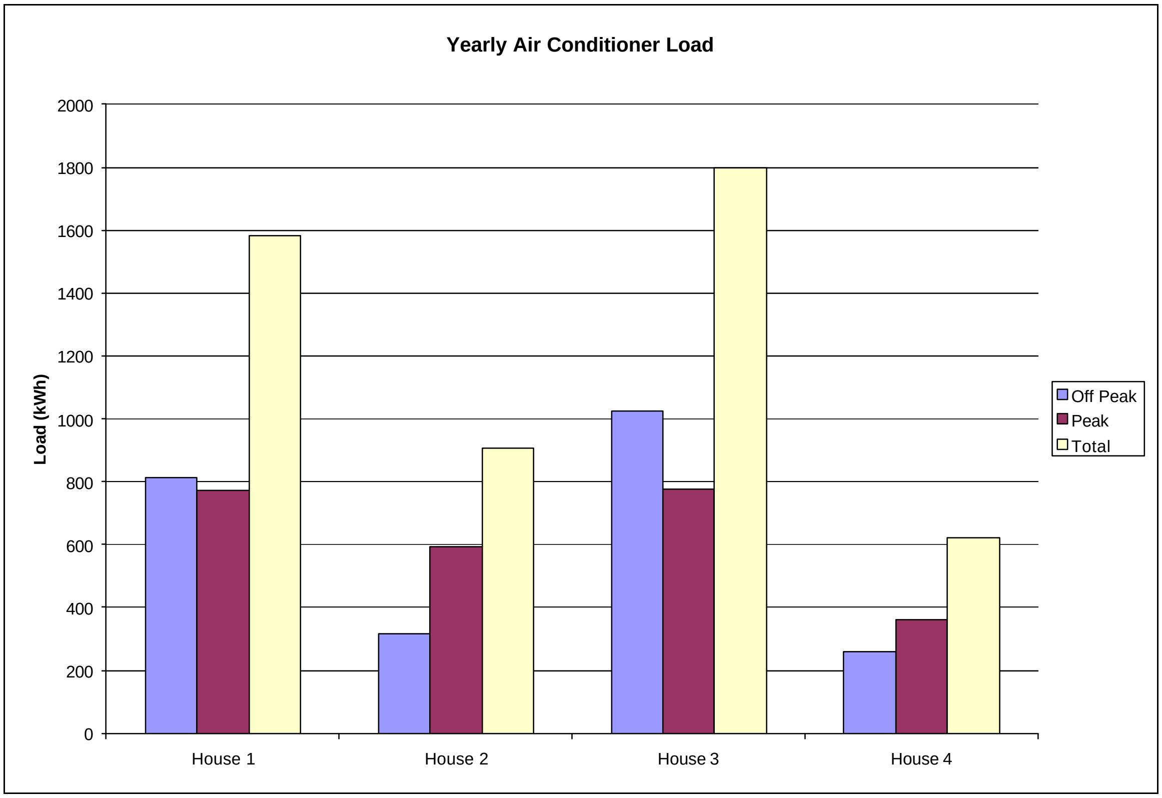
Cost using current local AEP TOU tariff (AEP Michigan tariff 016).



Graph 82

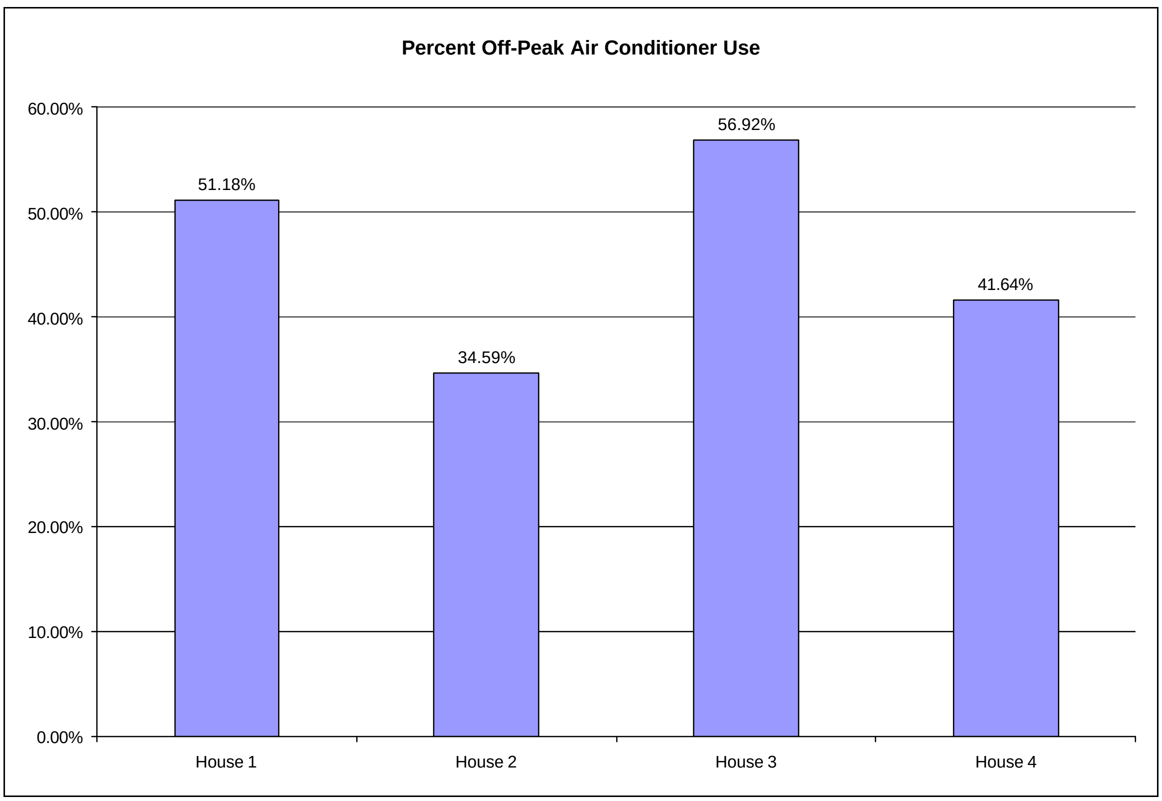
Total load comparison by house by month.

Air Conditioner

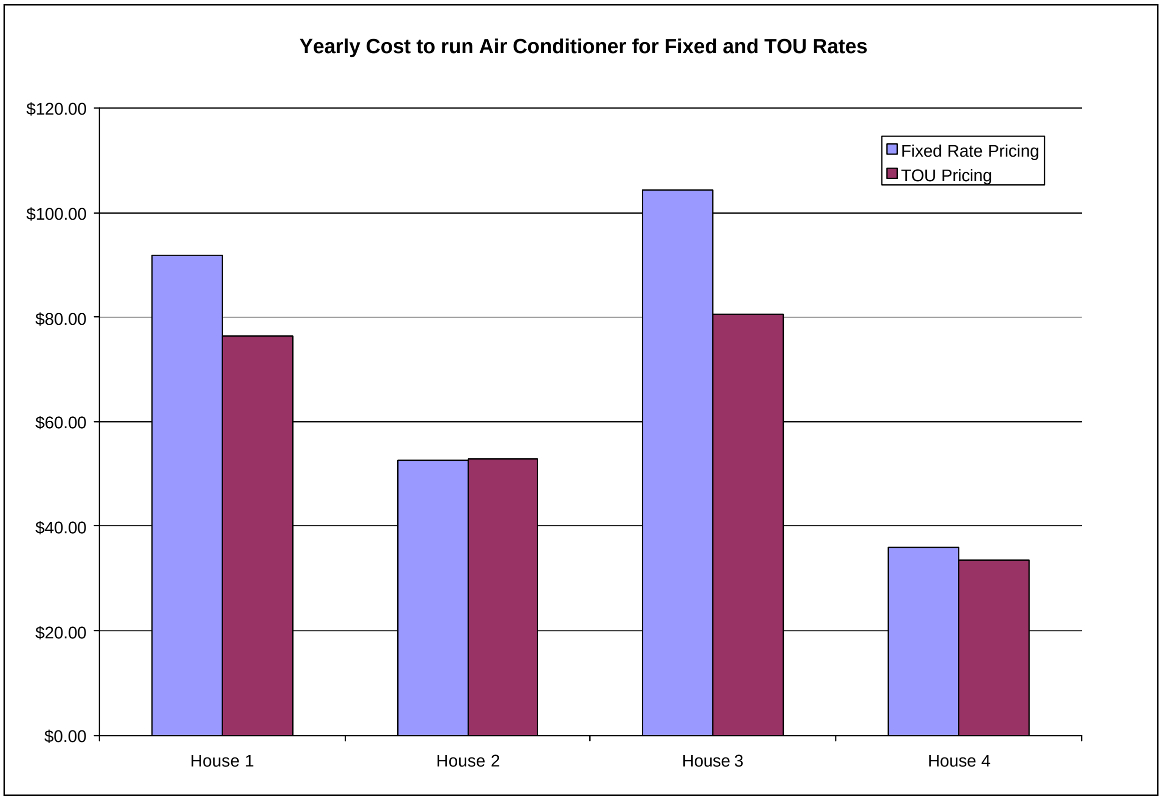


Graph 83

Total load from Jan to Dec 2005 in kWh.

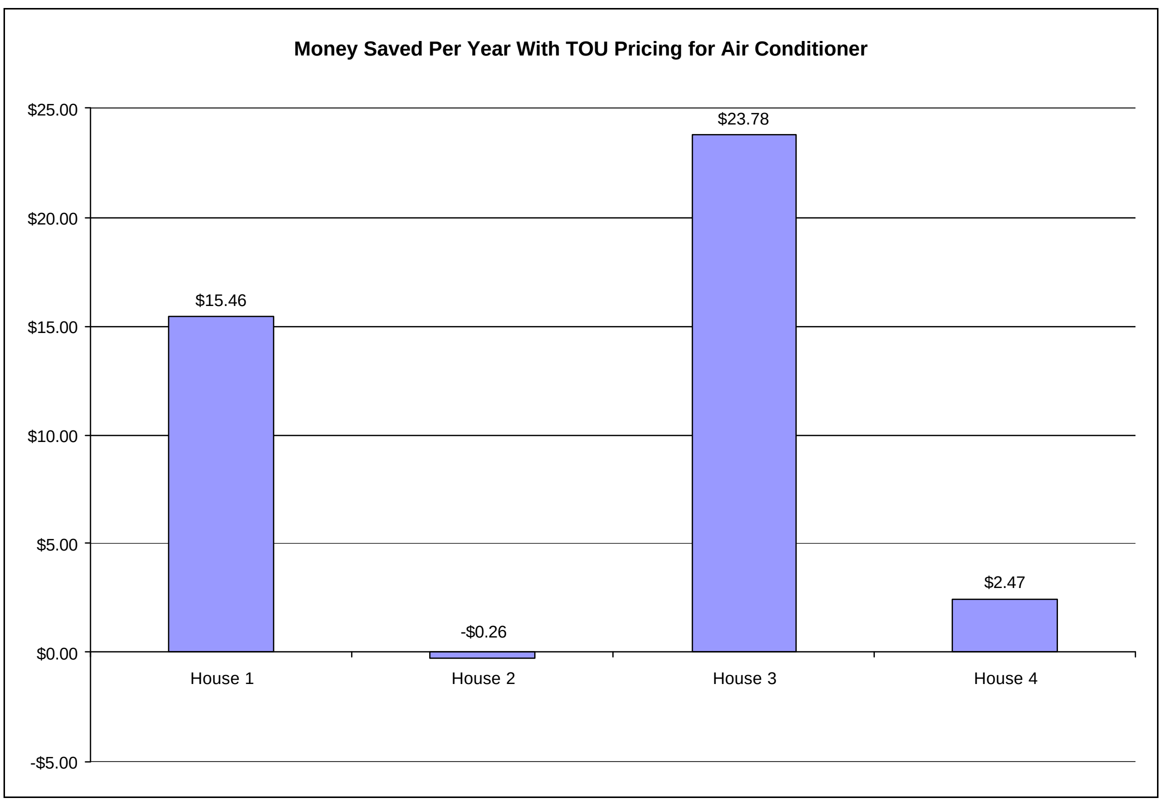


Graph 84



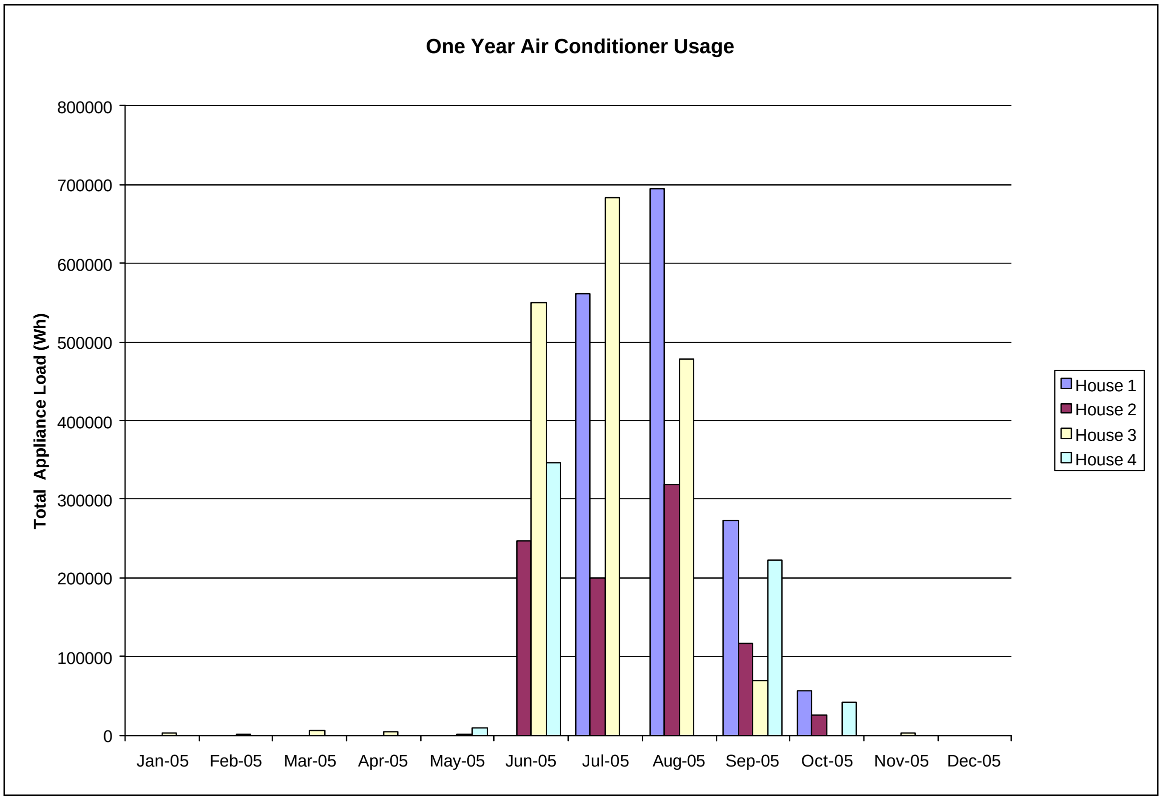
Graph 85

Cost using current local AEP TOU tariff (AEP Michigan tariff 016).



Graph 86

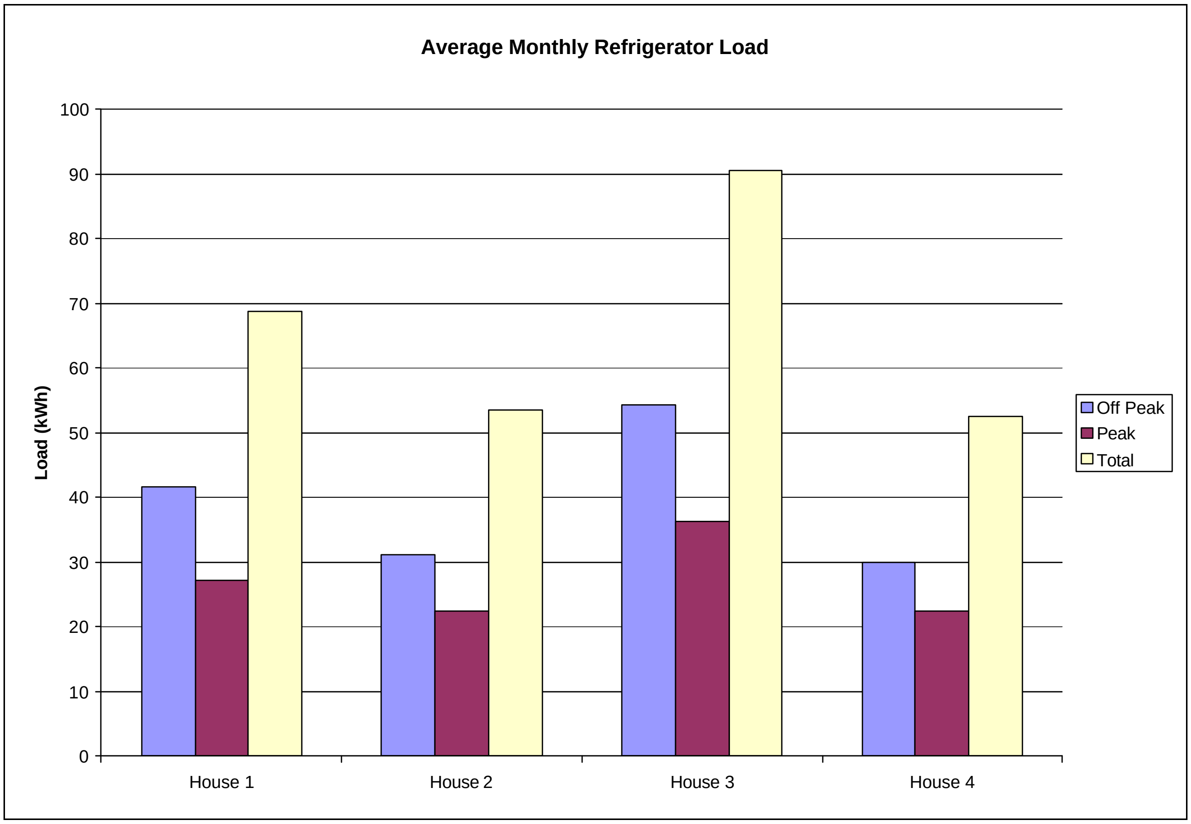
Cost using current local AEP TOU tariff (AEP Michigan tariff 016).



Graph 87

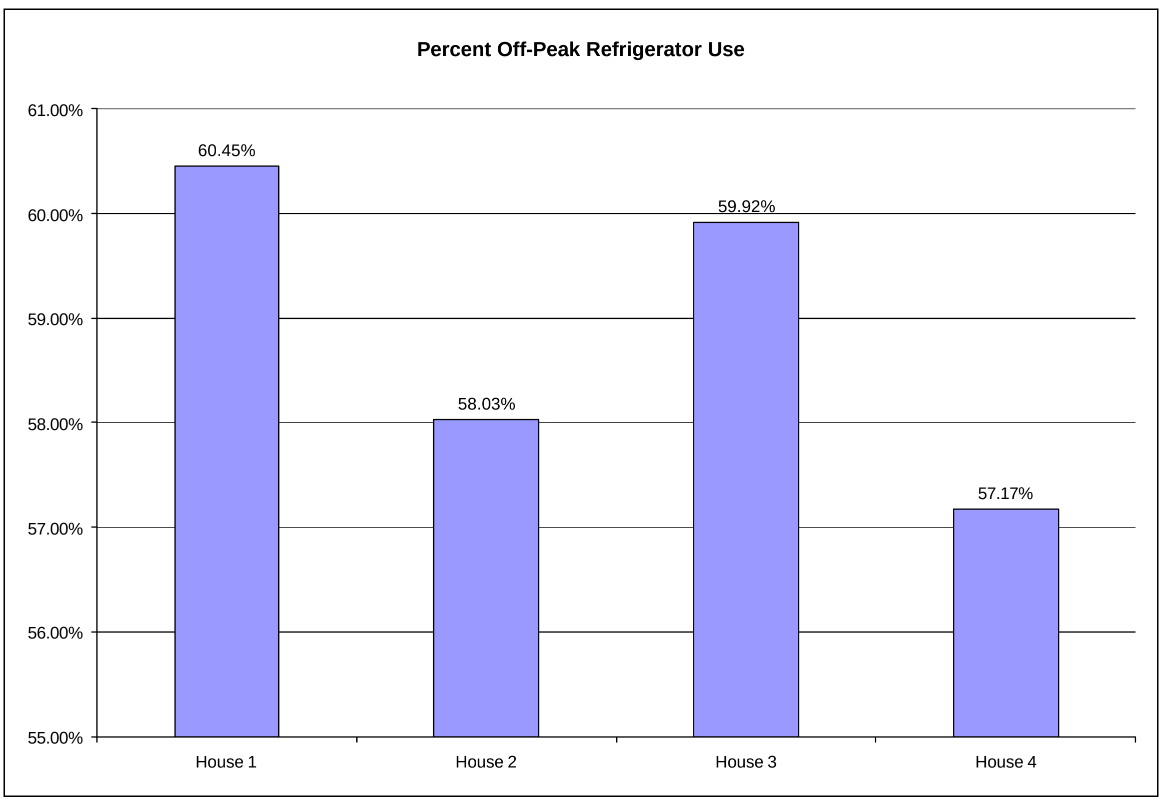
Total load comparison by house by month.

Refrigerator

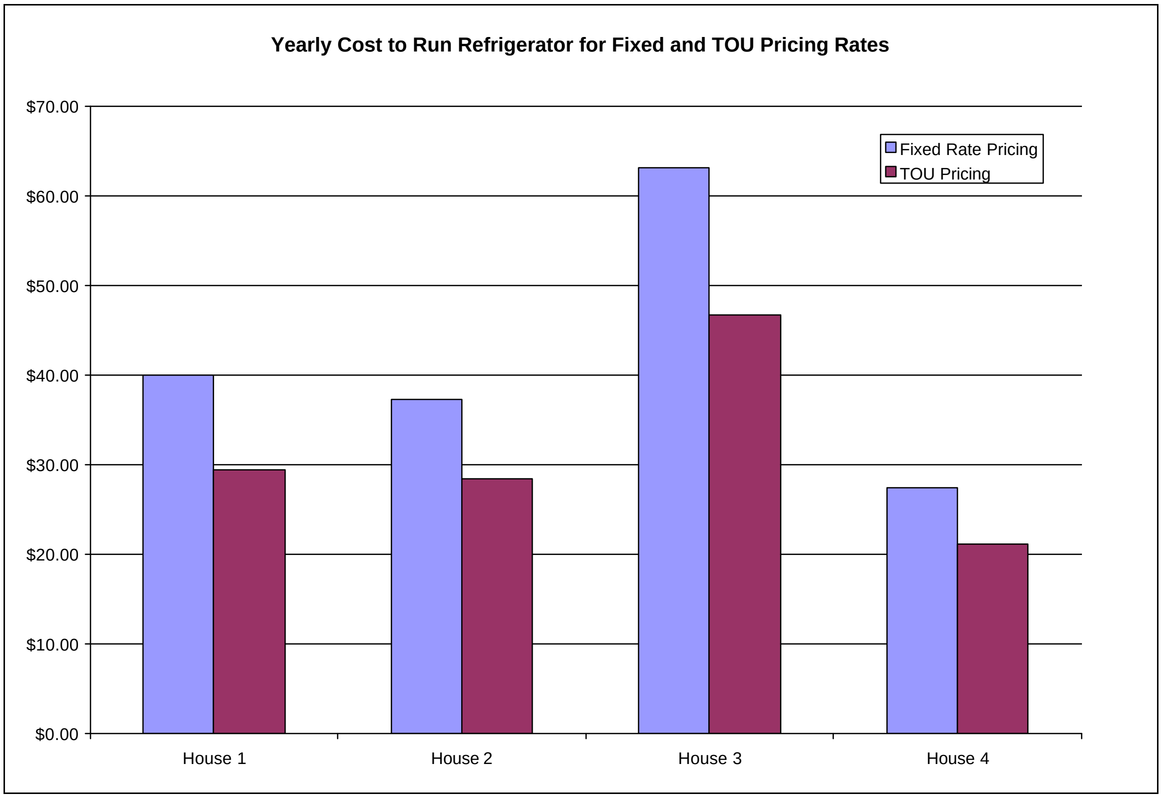


Graph 88

Total refrigerator load from Jan – Dec 2005 in kWh.

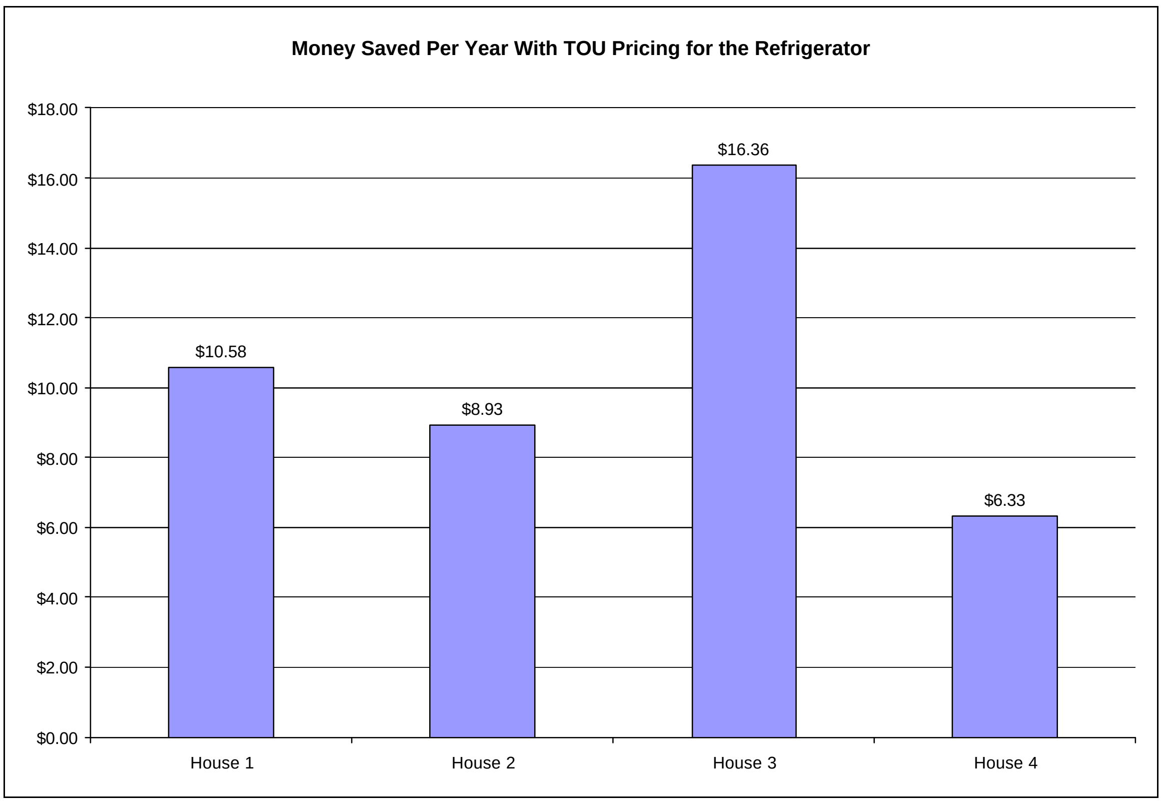


Graph 89



Graph 90

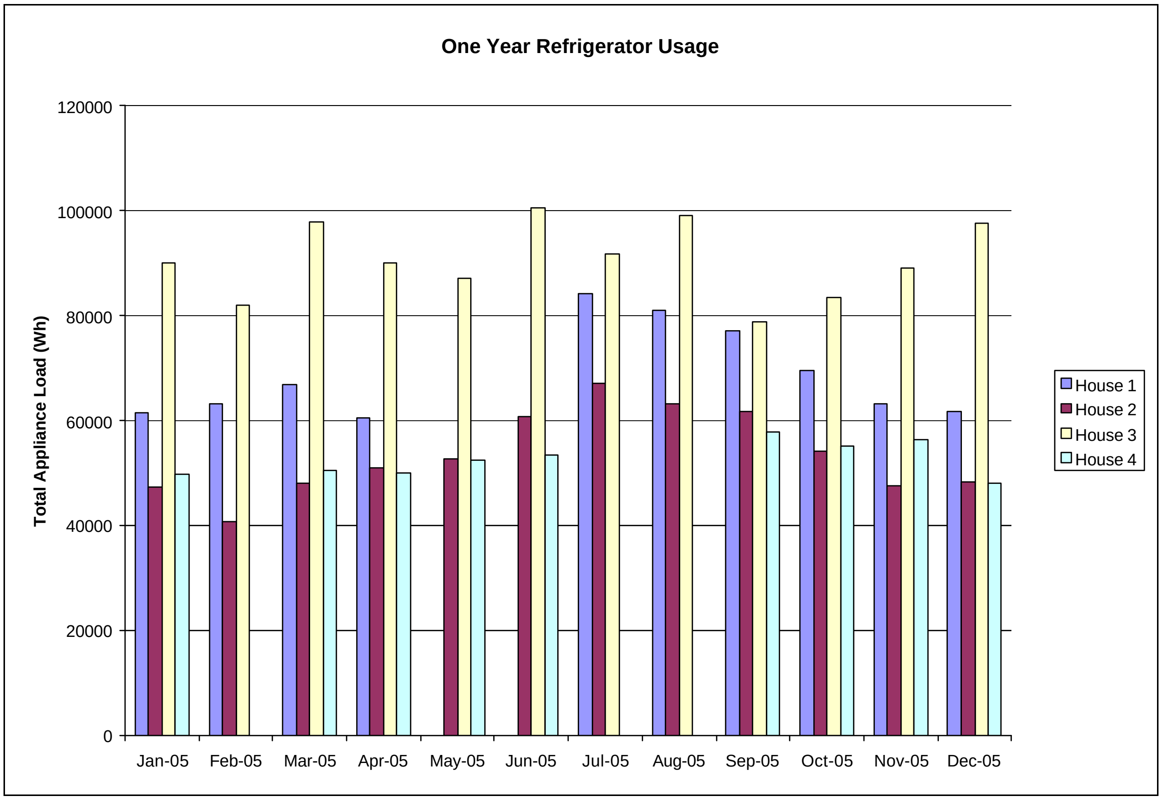
Cost using current local AEP TOU tariff (AEP Michigan tariff 016).



Graph 91

Cost using current local AEP TOU tariff (AEP Michigan tariff 016).

Money saved in one year on the refrigerator by using TOU pricing rather than fixed rate.



Graph 92

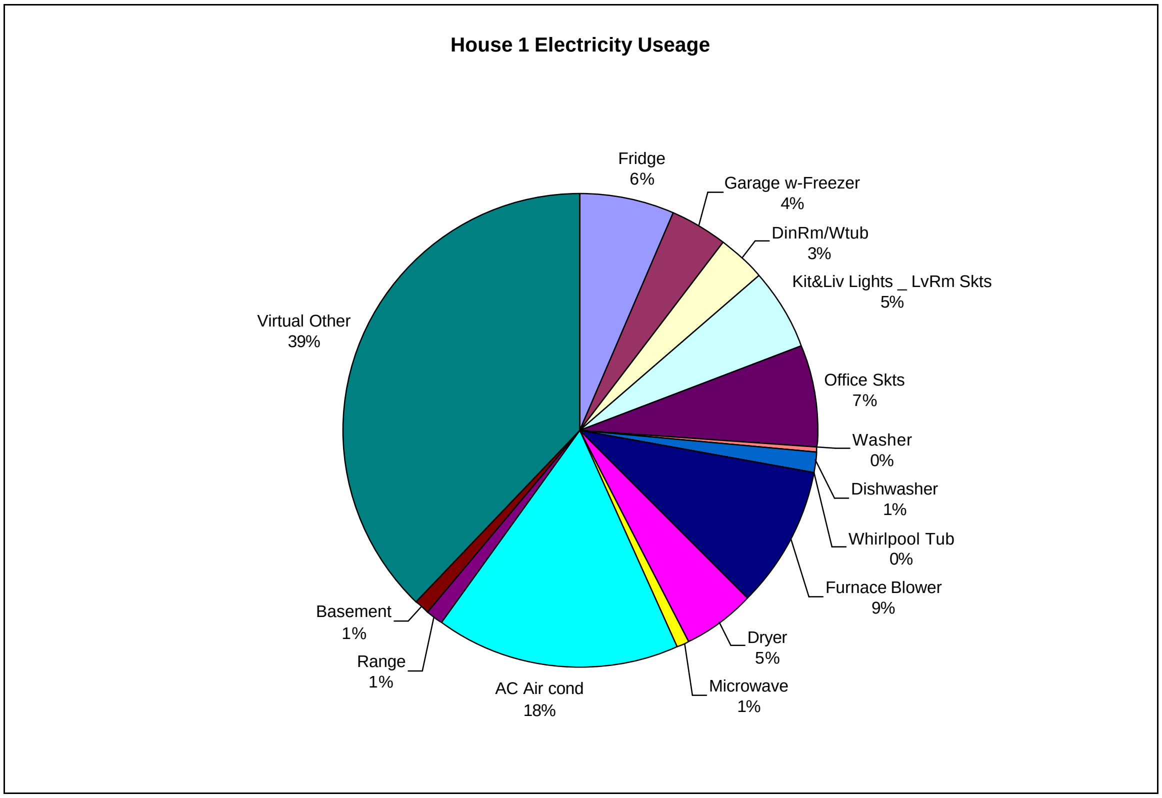
Total load comparison by house by month.

Data detail breakdown by home

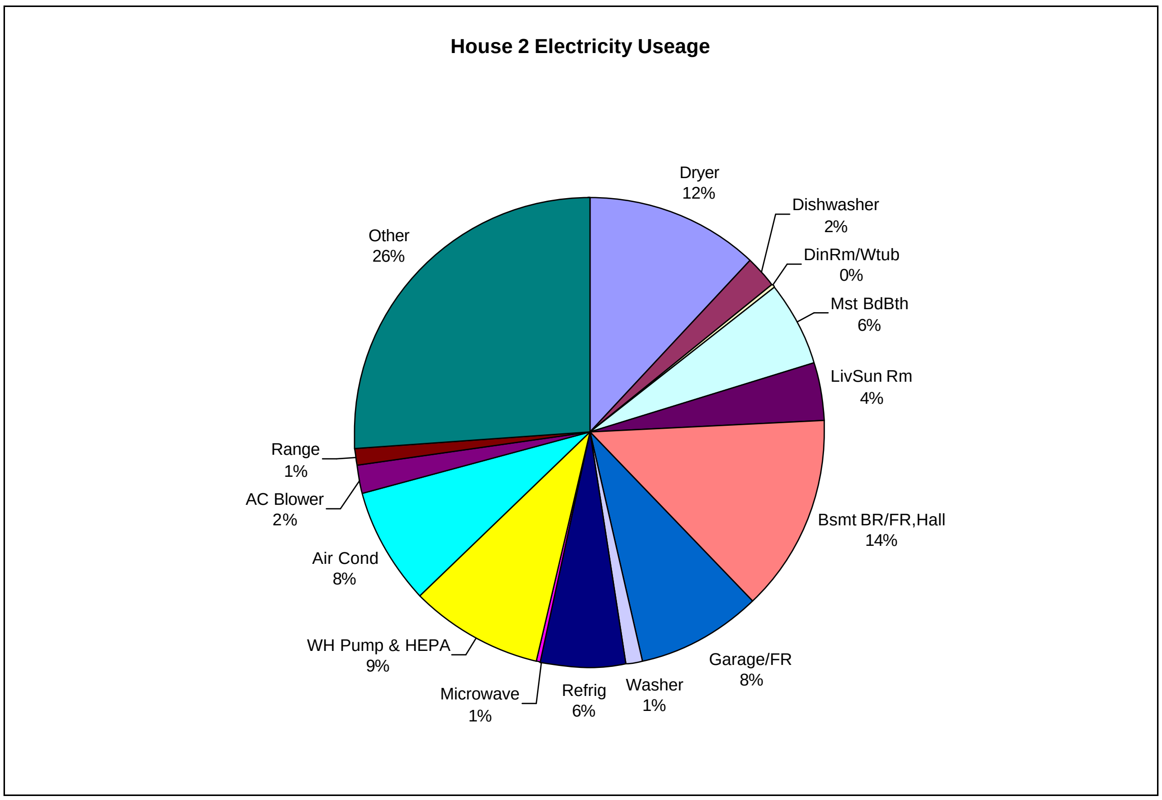
Note that since the circuit layout determined by the electrician was different in each home, the graphs are not entirely comparable. One home configured a bedroom as an office. Therefore the sockets on that circuit are titled as "Office Skts". If we were aware of a freezer located in the garage, it is noted on the pie chart. However since other items were also on the garage circuit, we could not determine the amount allocated to the freezer, although we suspect that a majority of the use on that circuit may have been from the freezer. Other notations may appear regarding each house.

In addition to the four main homes, data was gathered from several other homes that did not have the DSM appliances. Charts from these additional homes are included below.

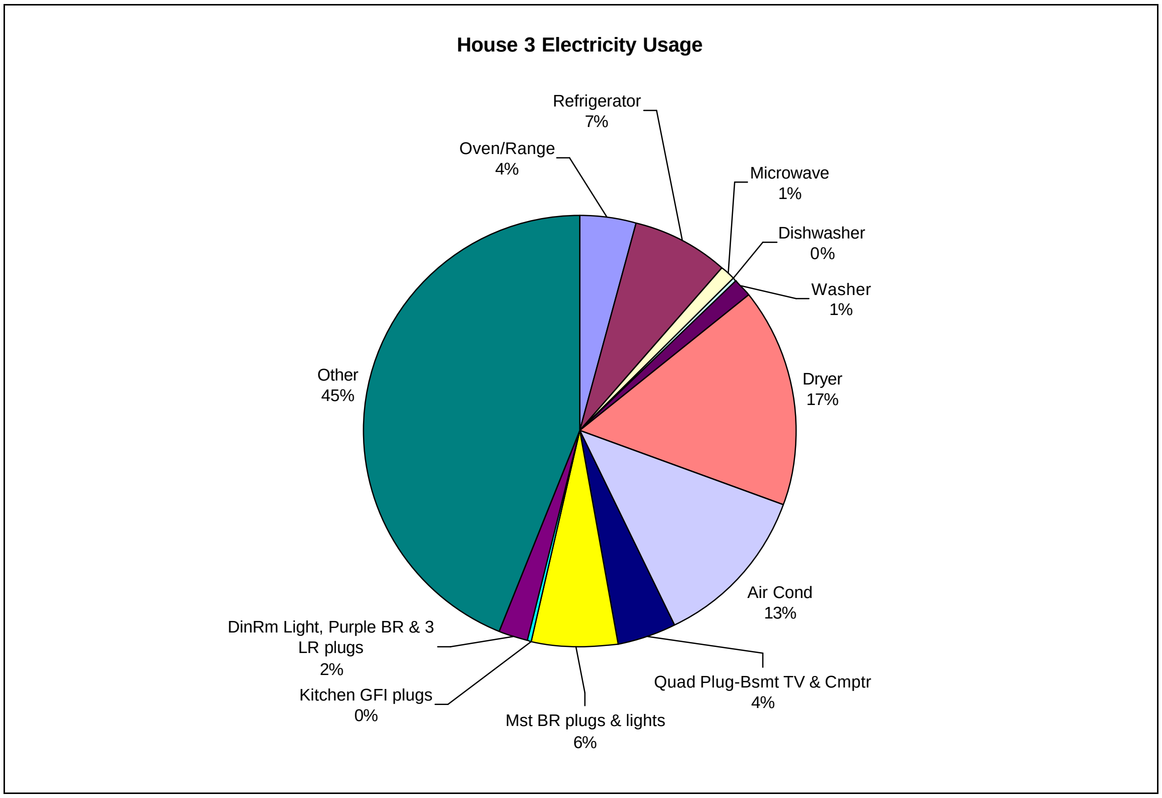
Individual home pie charts



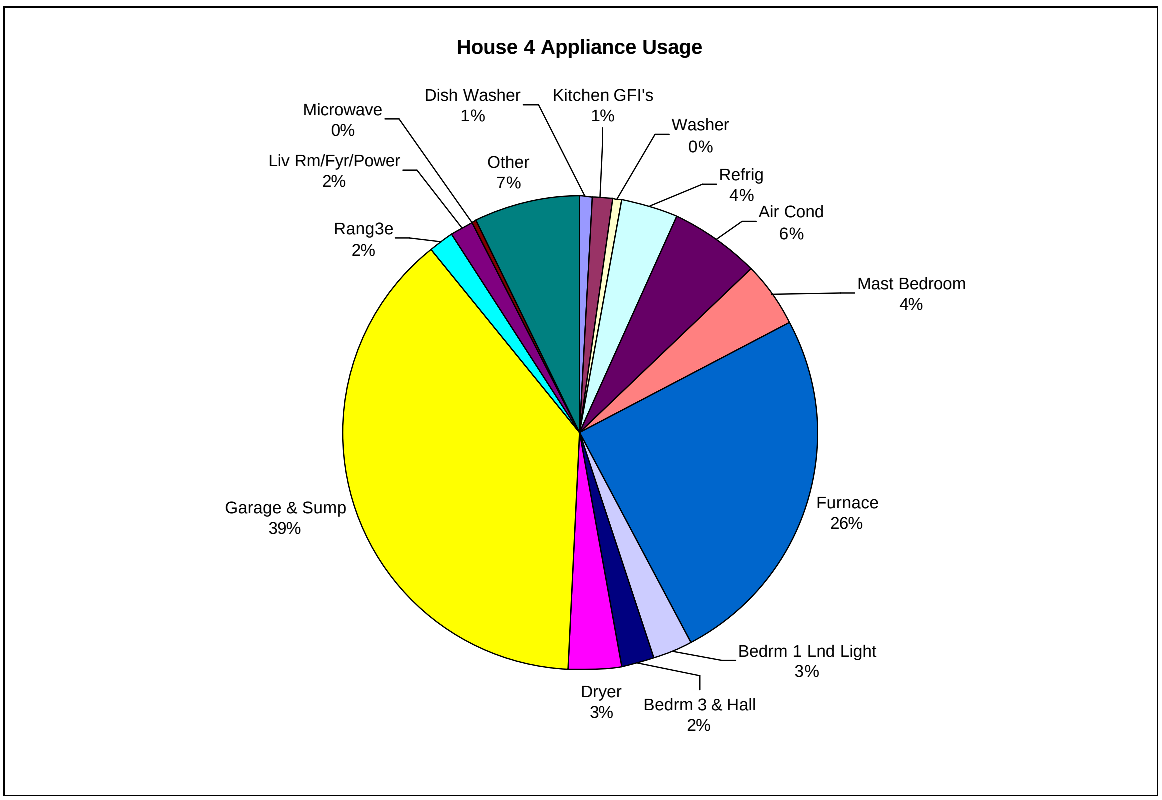
Graph 93



Graph 94

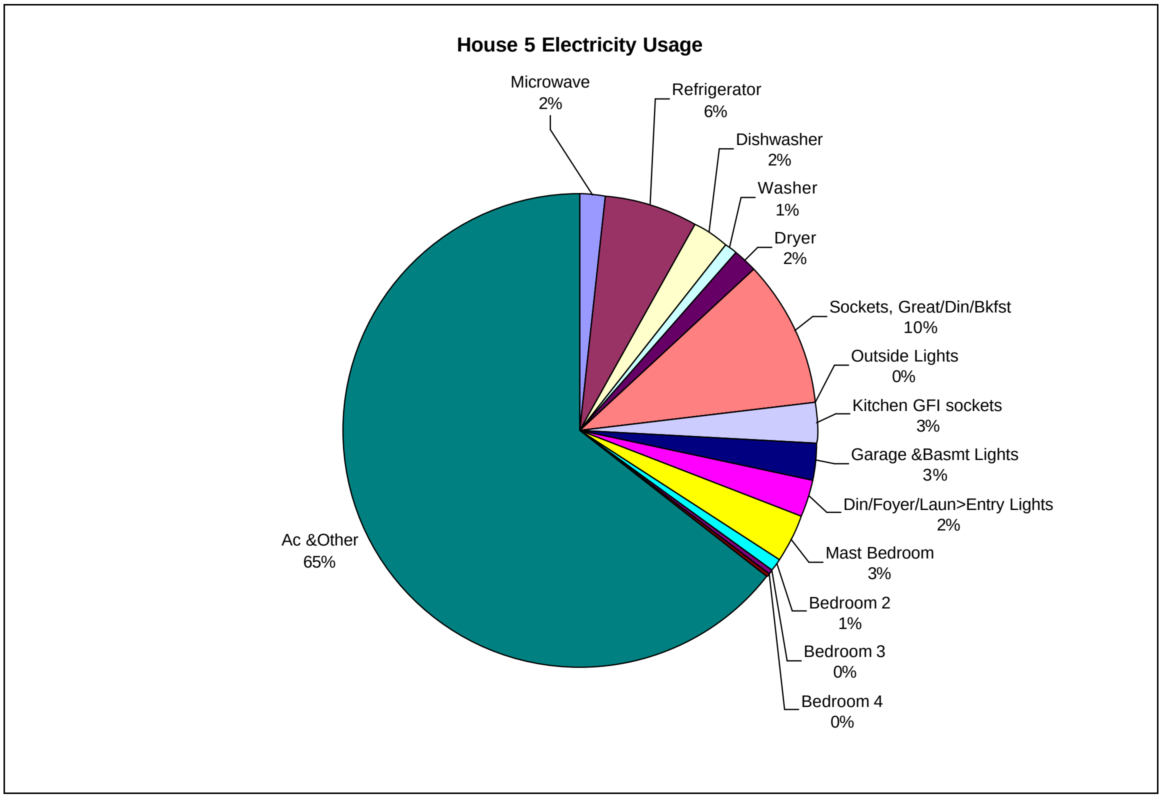


Graph 95



Graph 96

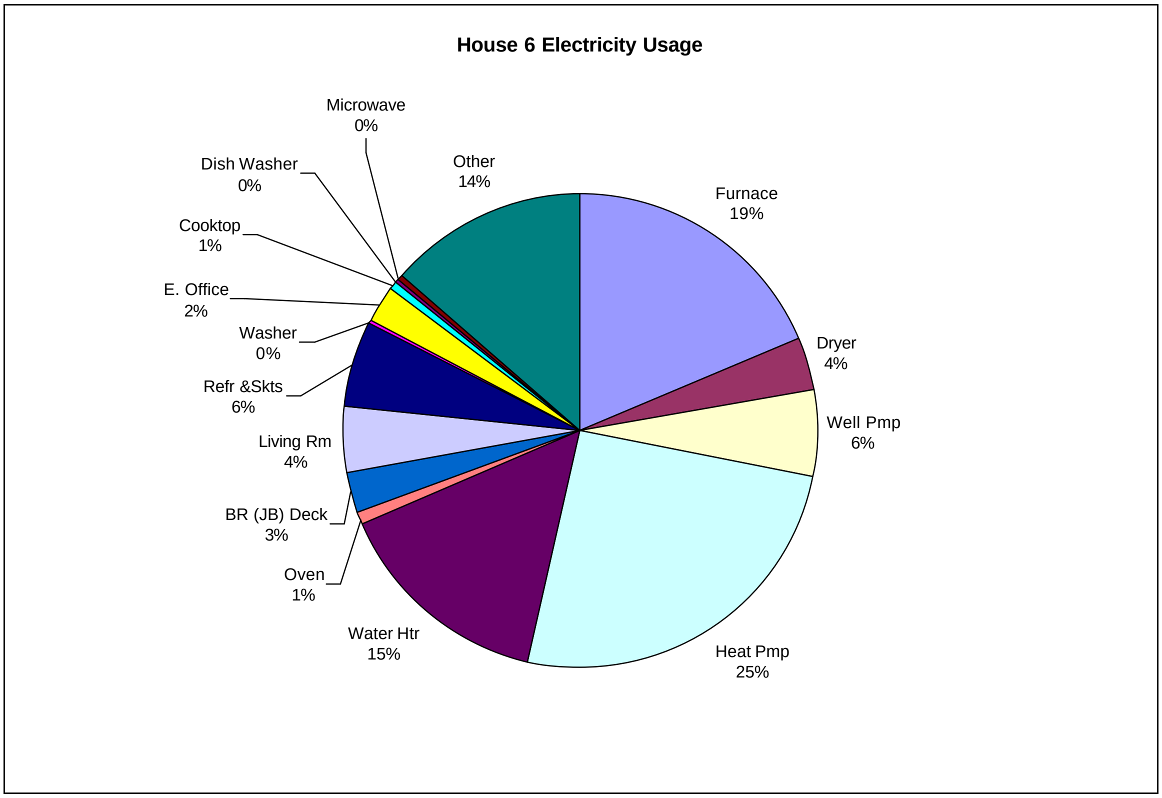
Note: House 4 had a dehumidifier running in the basement on "max dry" setting. This was plugged into the "Garage & Sump" circuit accounting for the excessive energy consumed on that circuit.



Graph 97

House 5: March through November of 2005 only

House #5 was located in Wisconsin. The family in house #5 moved out prior to completing a calendar year of data. This home did not have DSM appliances. The months represented are March to November 2005. Note that AC (HVAC) is included in the "Other" virtual channel for this home. This home had other special measuring devices as a part of the Department of Energy's Building America program. The DOE team wanted to measure AC separately and utilize the 14 sub-metered circuits for the other purposes listed. Note that the electrician was instructed to wire the circuits in house 5 to allow for better measurement of plug loads with a more convenient breakdown by circuit. This allowed, for example, specific measurement of each bedroom separately.



Graph 98

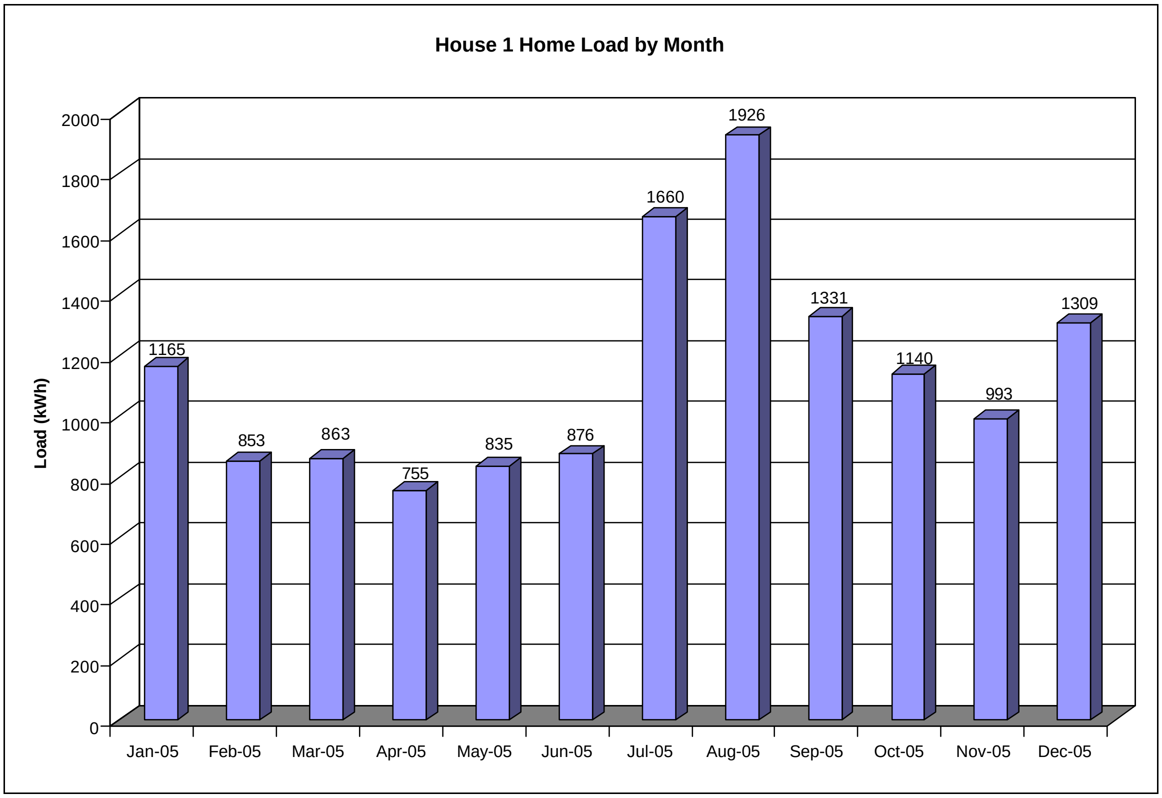
House #6 was a bit different from the main four homes in that it:

- did not utilize DSM appliances
- utilizes a well for tap water as well as the heat/cool thermal source for the heat pump
- utilizes a geothermal heat pump for both heating and cooling. The head pump is a 15-year old Carrier unit. To accurately compute HVAC totals for this home, you would need to include the heat pump, furnace and a portion of the well pump. Obviously these would be difficult to compute accurately.
- contains an electric water heater (the other homes were all natural gas units)

Note that with a total electric home, the appliances as a percentage of the total home may appear smaller since they are skewed down by the larger total electric home demand.

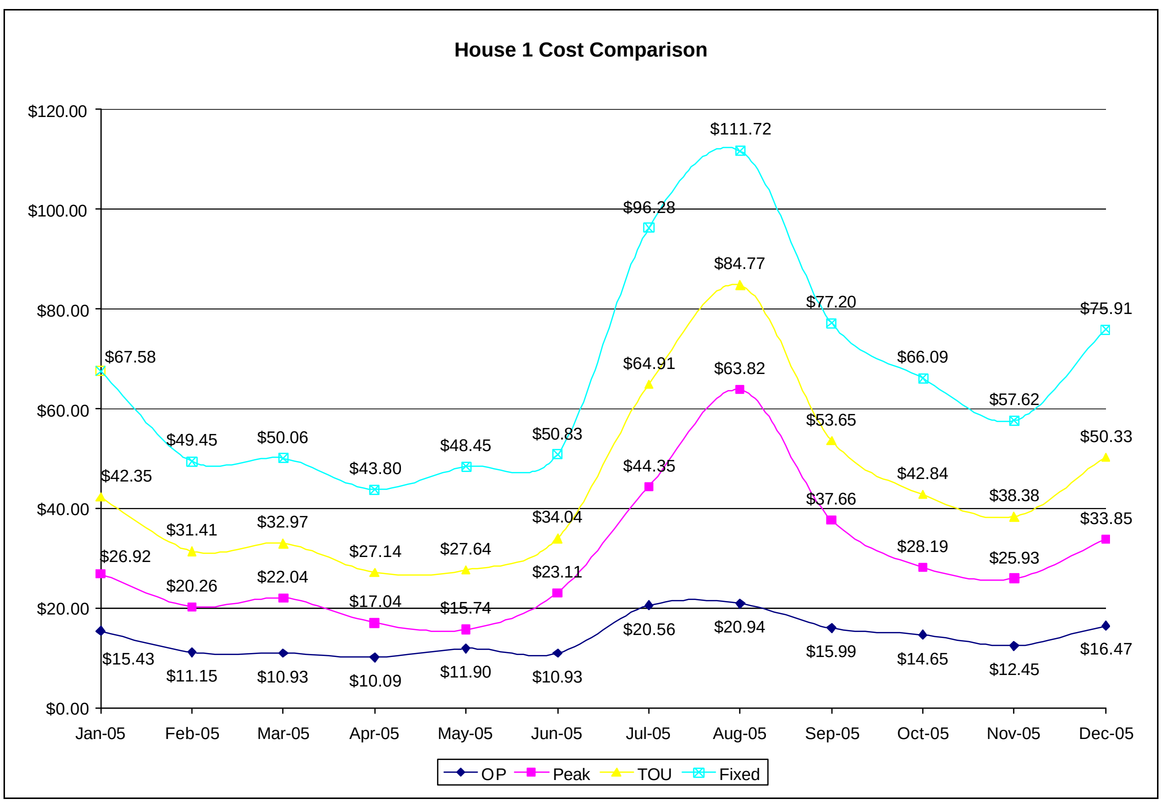
Individual home loads by month

Graphs 99-110 include a set of two graphs for each home. The first of each set of two is the kWh for that home by month. The second graph of each set compares peak, off-peak, and fixed prices with an additional line showing the difference (savings) in TOU compared to fixed prices. The second in each set is relative to the current TOU tariff for the Woodridge area.

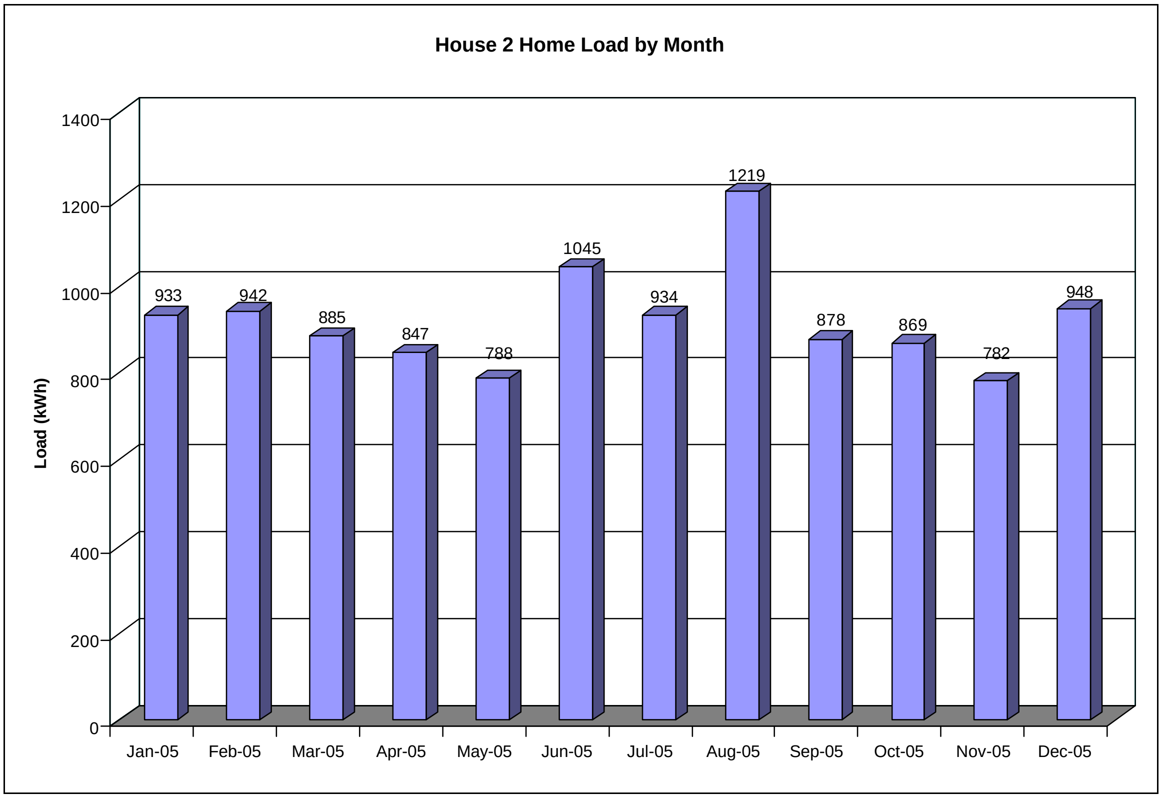


Graph 99

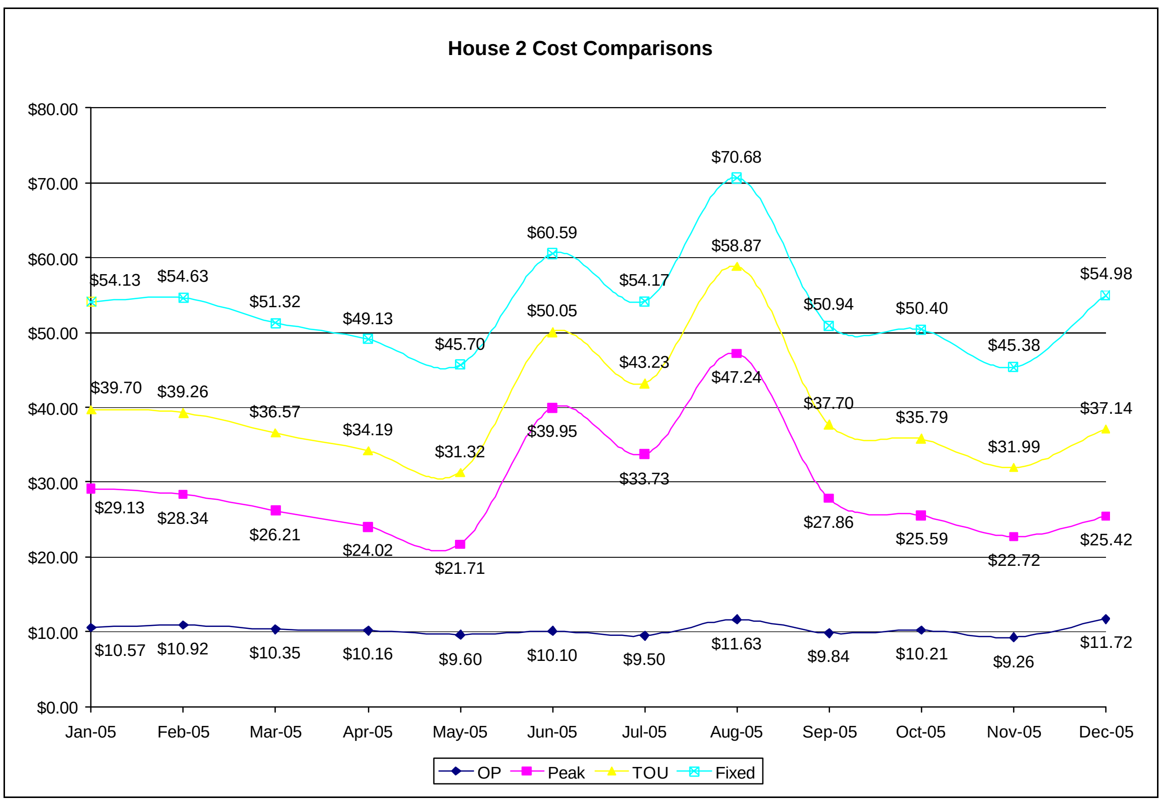
Home 1 was missing some pieces of data for May and June of 2005. Data was substituted with data from May and June 2004. Cost comparisons below compare fixed rate tariff with the actual TOU cost.



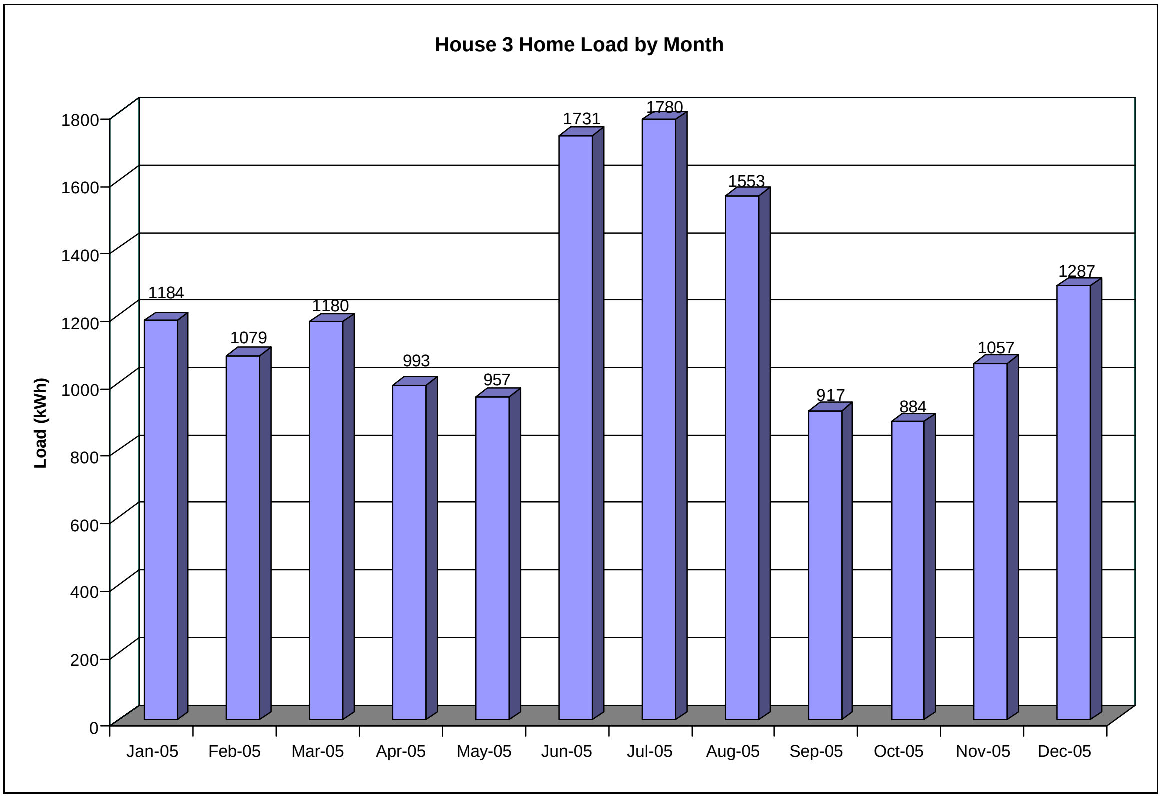
Graph 100



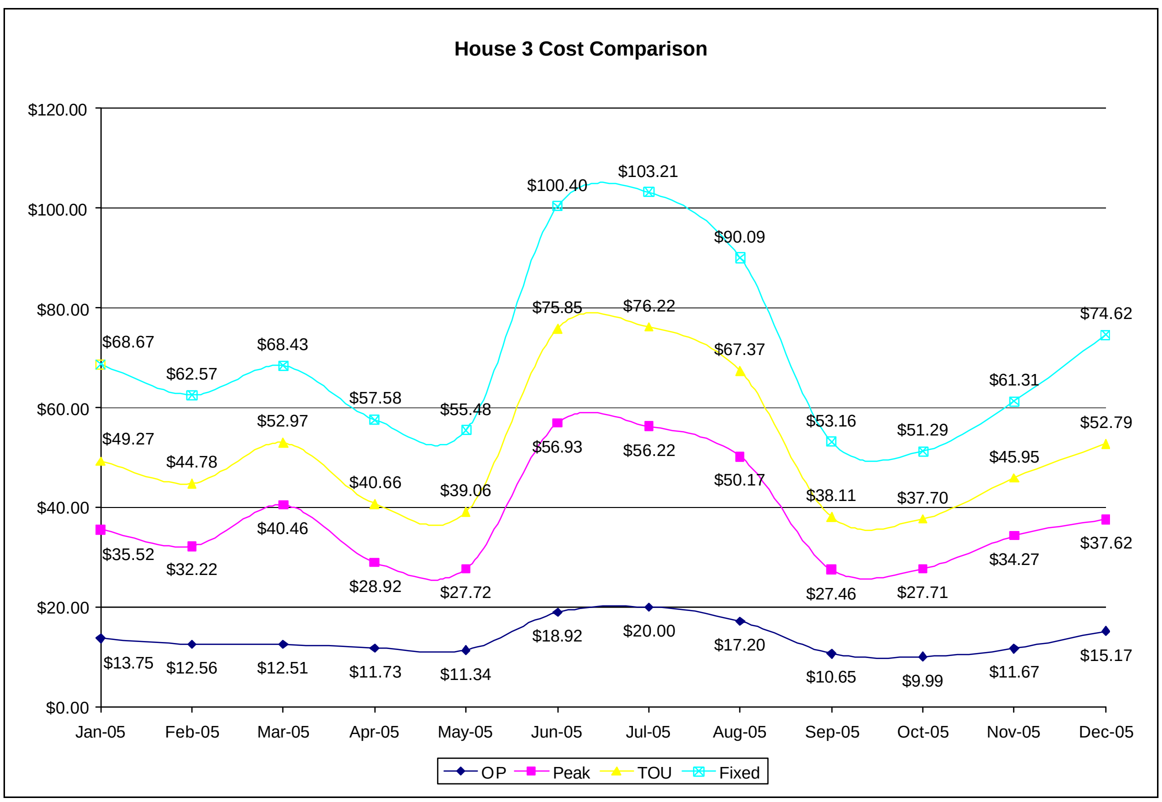
Graph 101



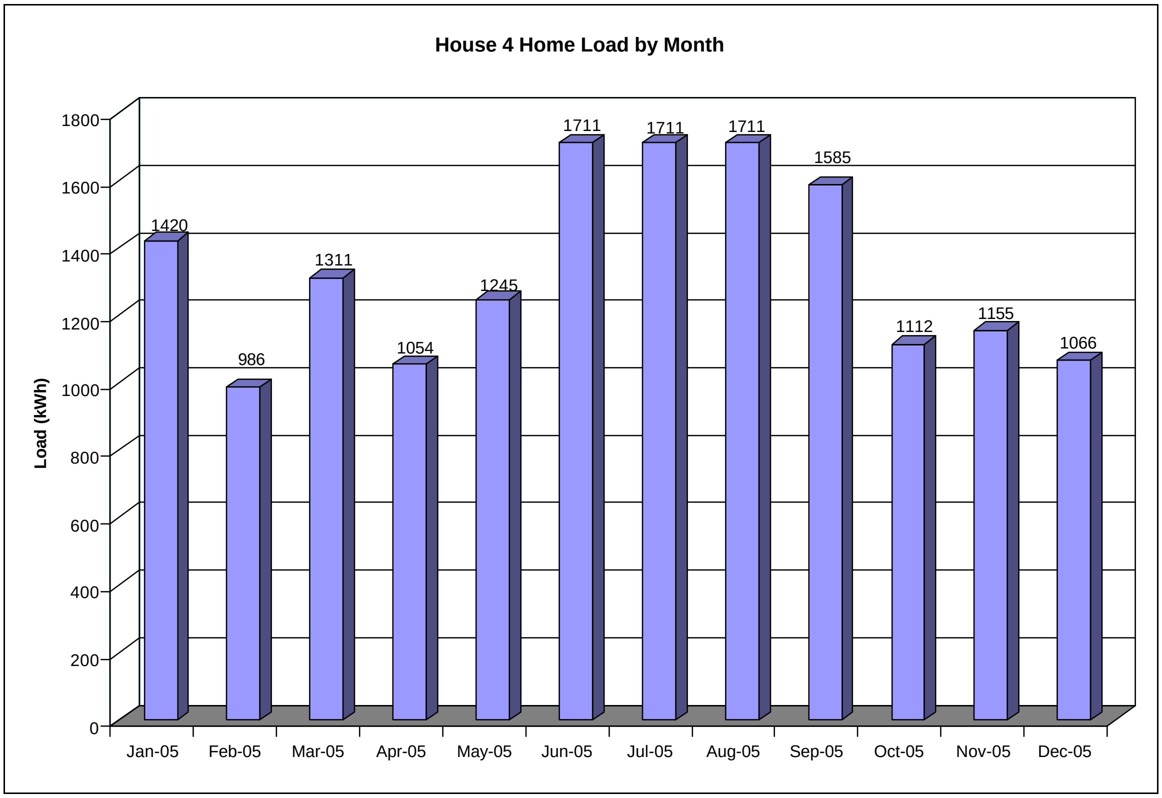
Graph 102



Graph 103

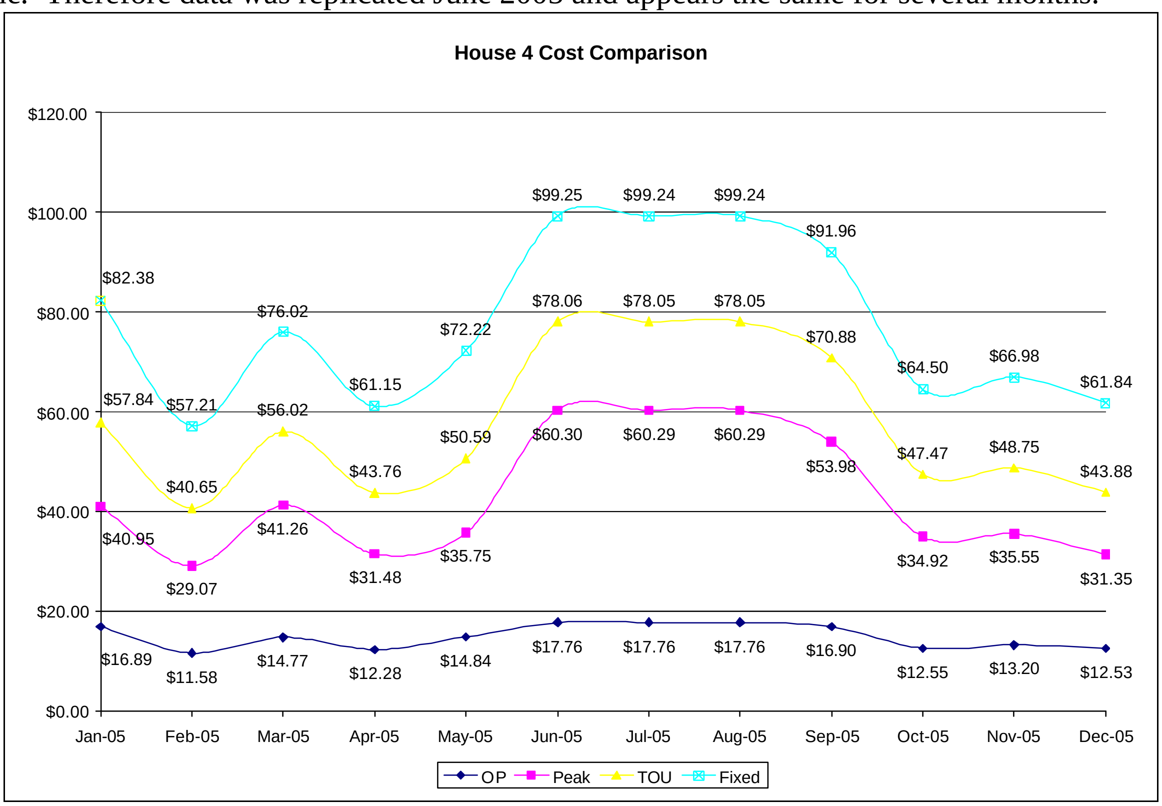


Graph 104

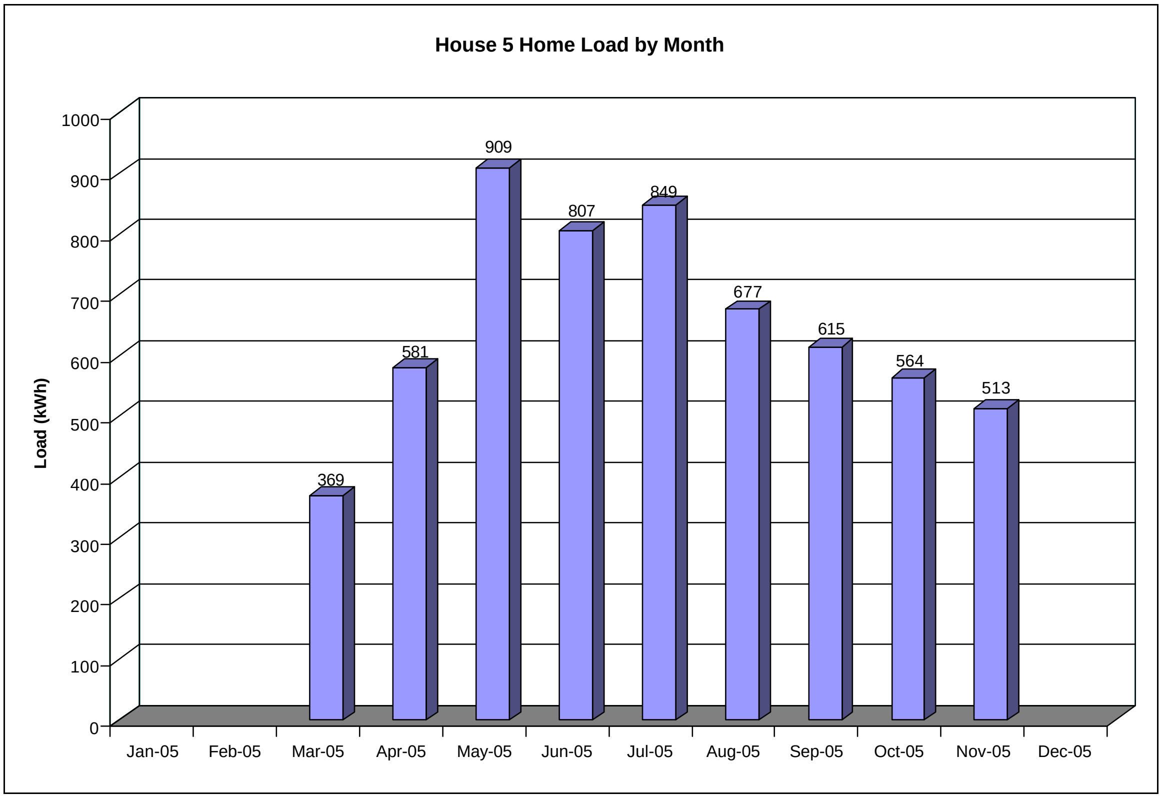


Graph 105

Some data was missing for part of Feb 2005. This data was replaced with Feb 2006 data. There was missing data for July and August. There were no corresponding months from other years for this home. Therefore data was replicated June 2005 and appears the same for several months.

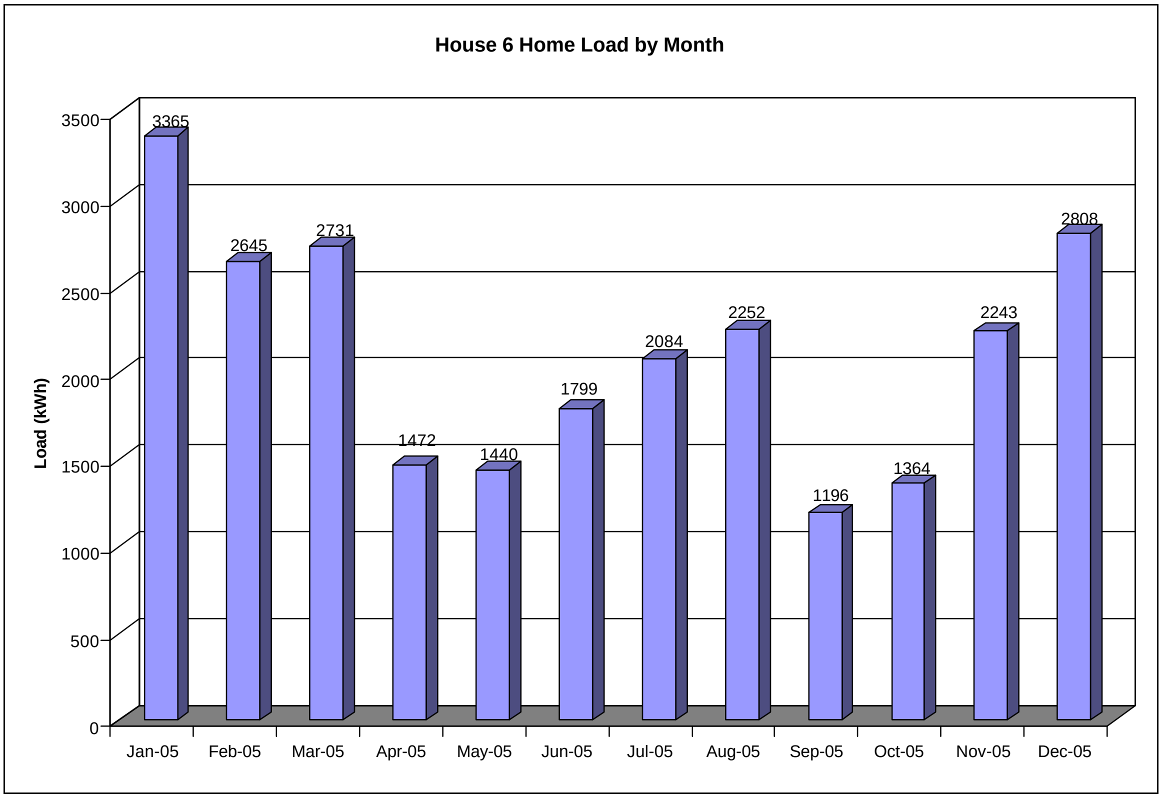


Graph 106



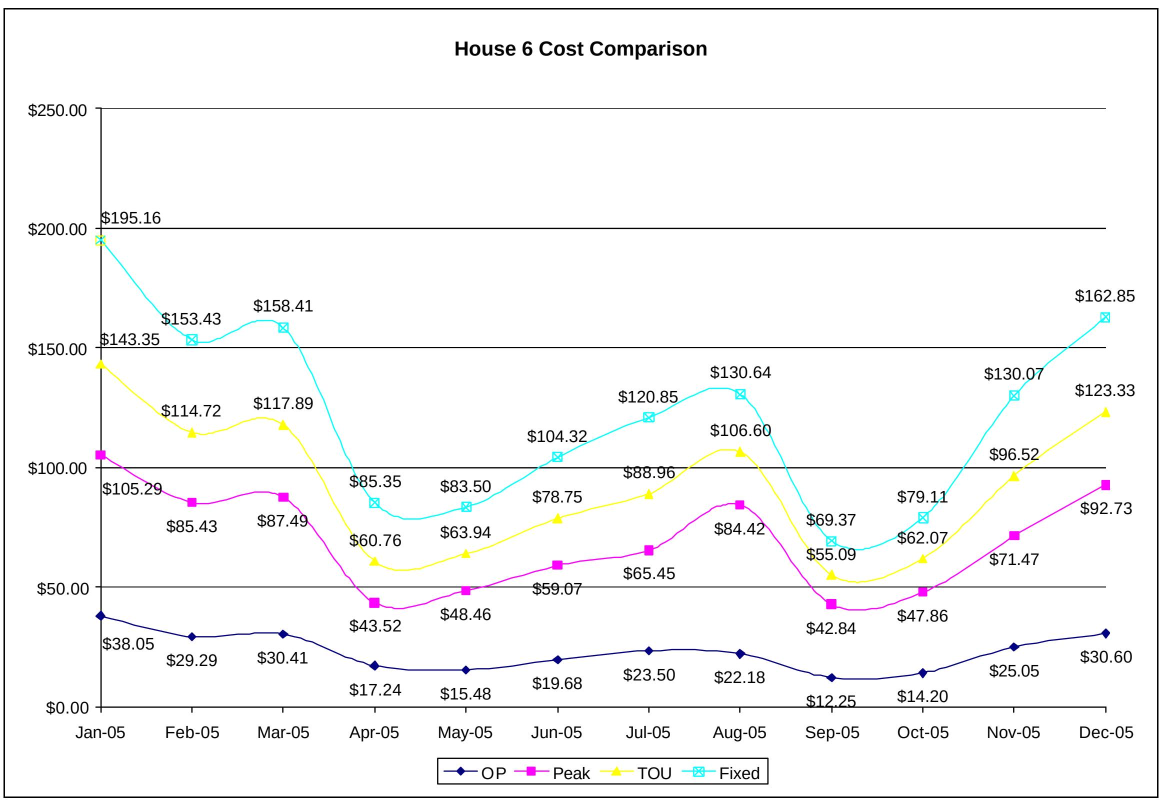
Graph 107

House #5 was located in Madison Wisconsin. Data represents March 2005 to November 2005. House #5 was not on a TOU tariff and was in a different region. Therefore the cost comparison graph comparing TOU with Fixed rate tariff has been omitted for house #5.



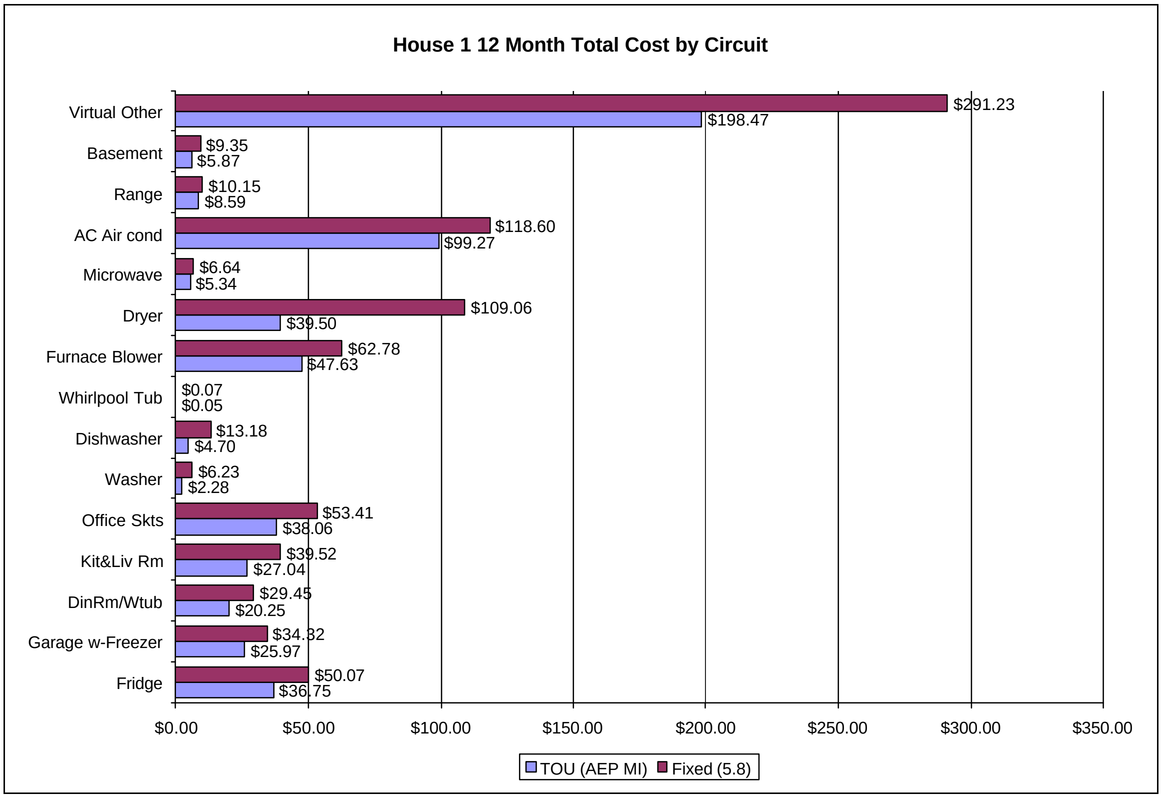
Graph 109

House #6 was all electric and the only home with an electric water heater and an independent water source (note the well pump circuit). The heat and AC source is a Carrier geothermal unit.

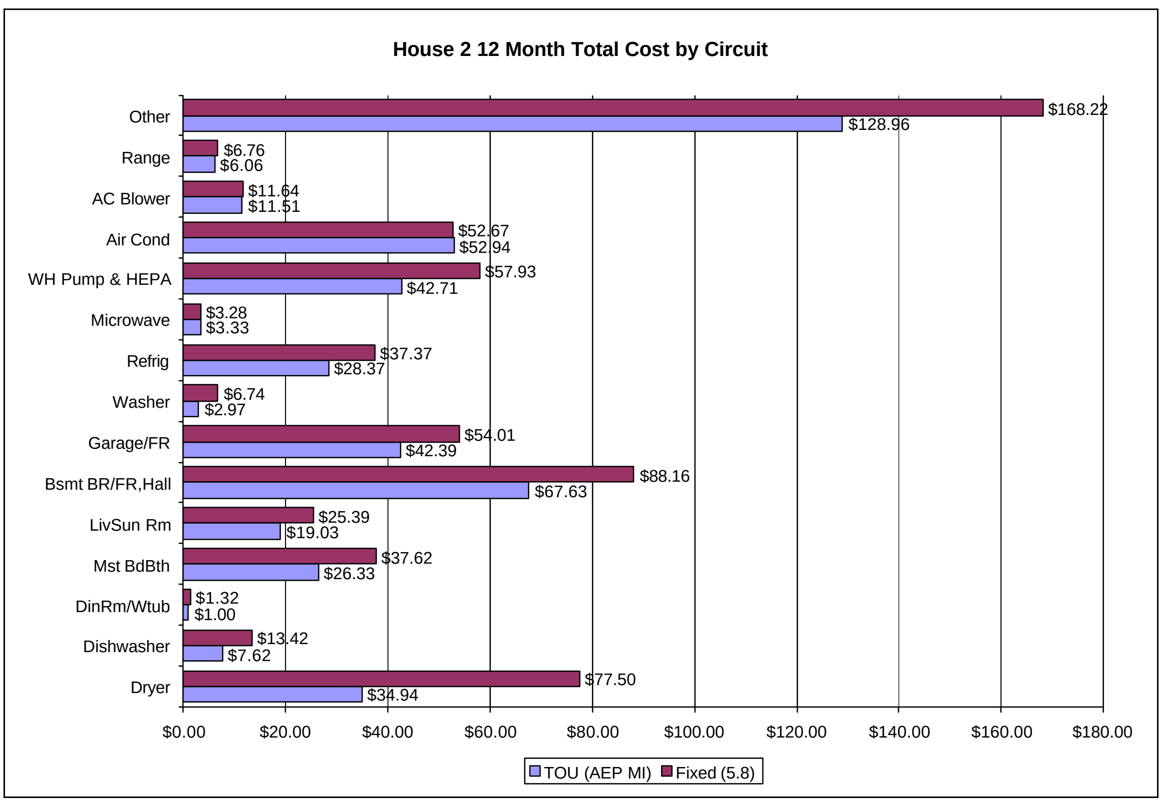


Graph 110

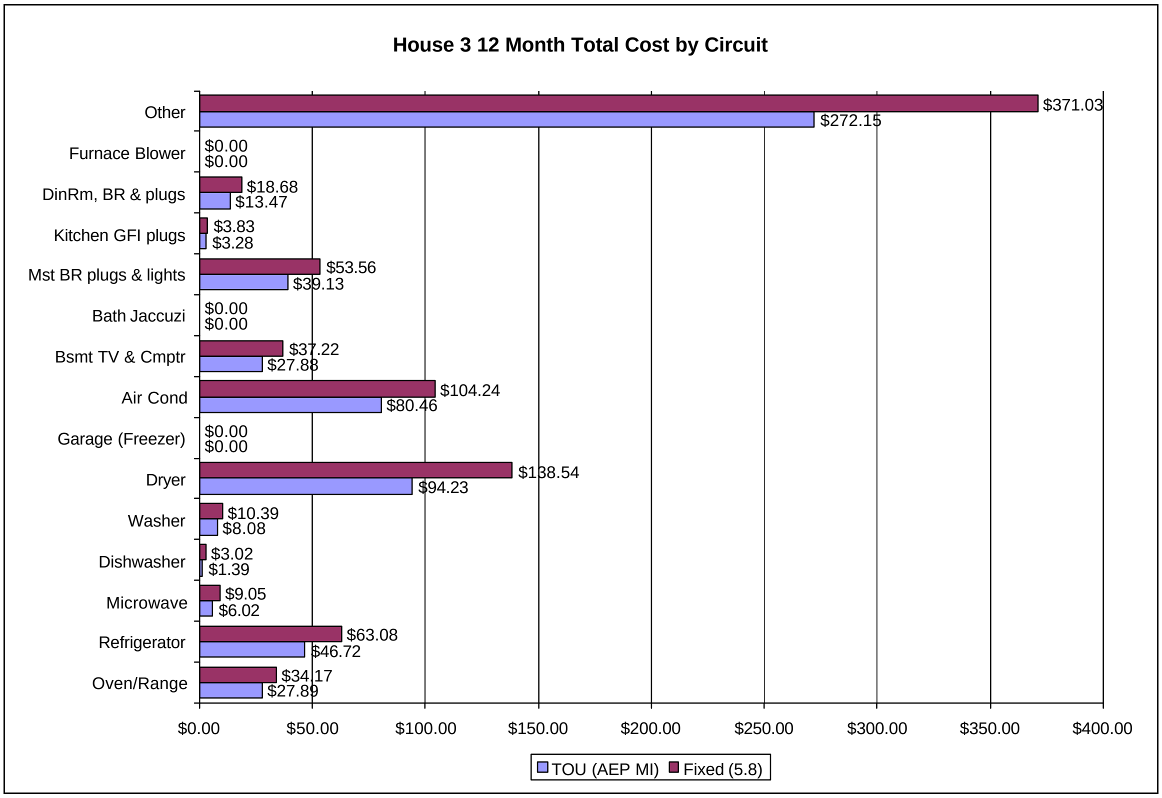
Annual cost for individual homes & circuits



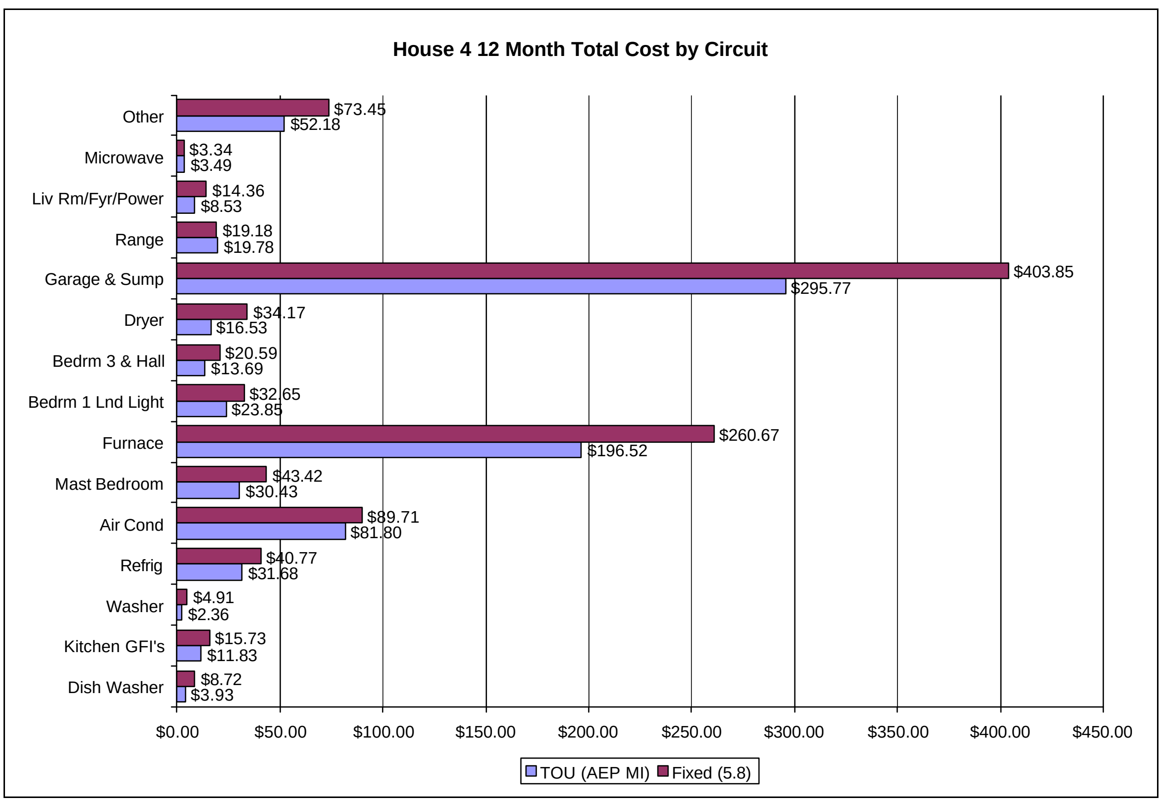
Graph 111



Graph 112

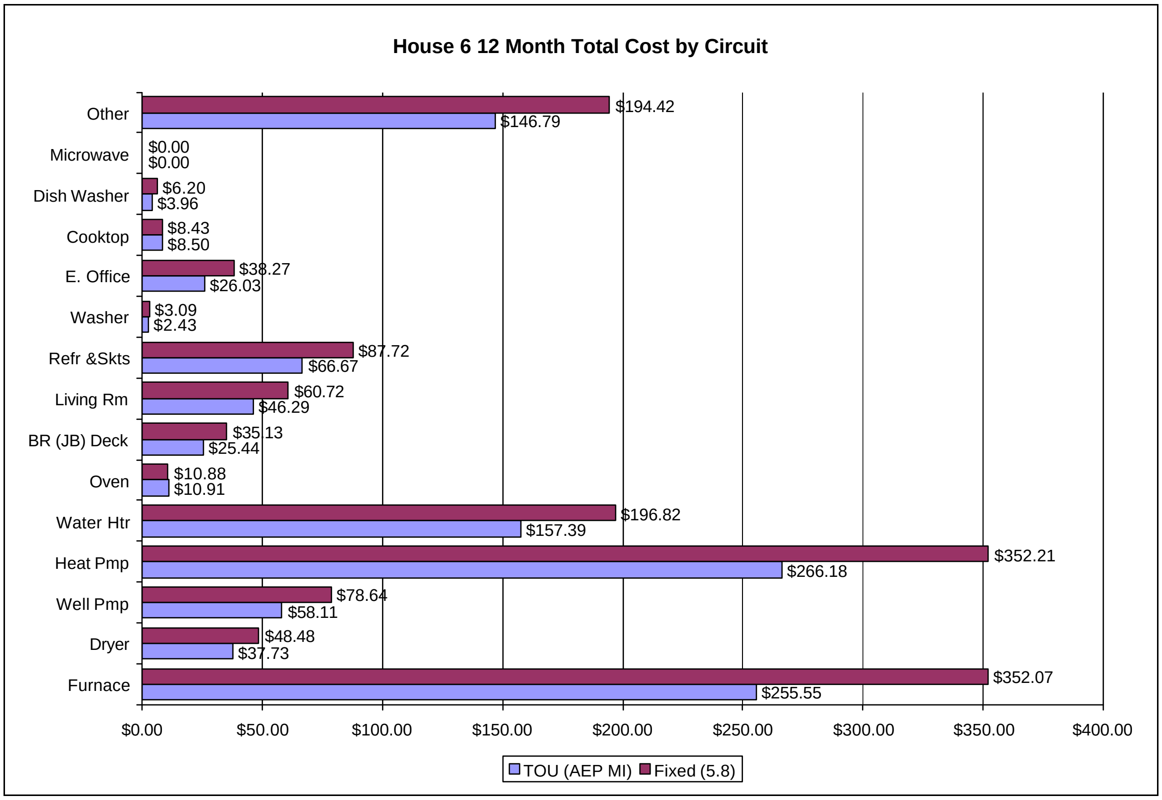


Graph 113



Graph 114

Note: House #5 was omitted as it did not have a full year of data.

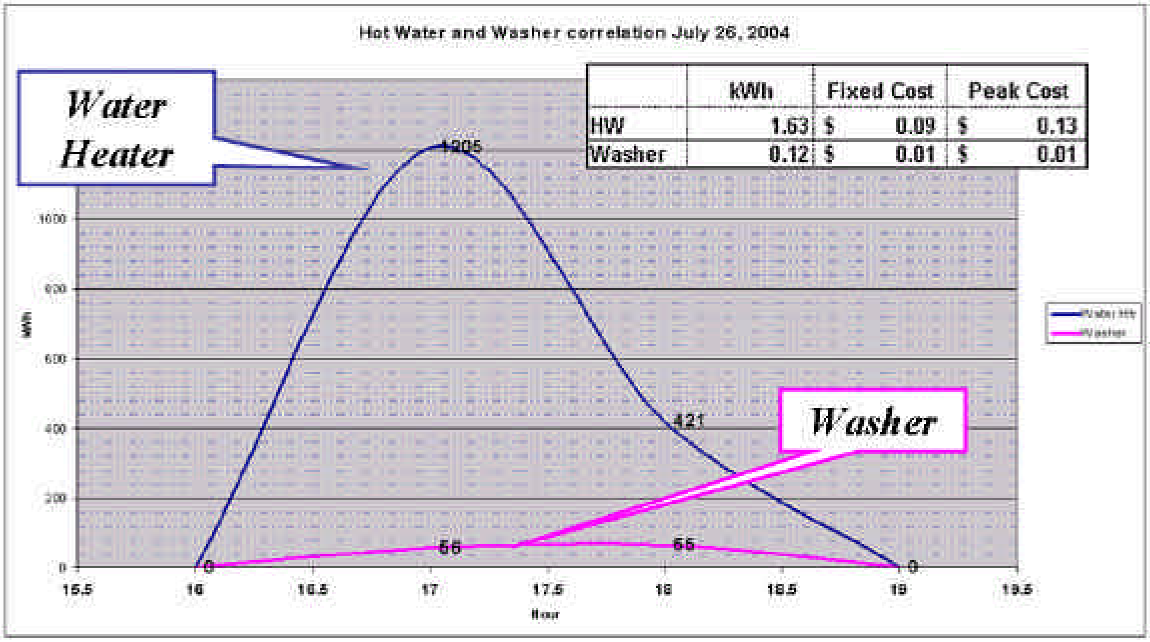


Graph 115

Washer & water heater correlation

Graph 116, below, shows the correlation between a washer and water heater. Data from the home with an electric water heater was scanned until we found an incident where it appears that the only thing consuming water was a load of laundry. This data was extracted and graphed below. Although we couldn't guarantee with 100% accuracy that the consumer did not run hot water from a faucet at the same time, the other activity in the home seemed to support the conclusion that our assertion is accurate.

There are some modern clothes washers that accommodate a multi-temperature wash for the purpose of enzyme-based detergent optimization along with the ability to get out grease-based stains (a higher temperature than what would allow the enzymes to work). There are also washers with the internal heating element that is used for a sanitary cycle that is utilized, optionally, to sanitize laundry. (For example when a family member has been ill, the sanitary cycle will help eliminate remaining germs or contaminants in the consumers bed-sheets or clothing. Clothing worn by workers in the medical profession also benefit from this feature.) If the sanitary cycle is used, an additional 1,400 watts will be called upon in the washer for a brief period of time. This would raise the washer consumption in the graph below. However, since the recovery on a typical electric water heater is much longer and generally consumes about 4,500 watts, you would still see a significant difference in this type of washer / water heater comparison.



Graph 116

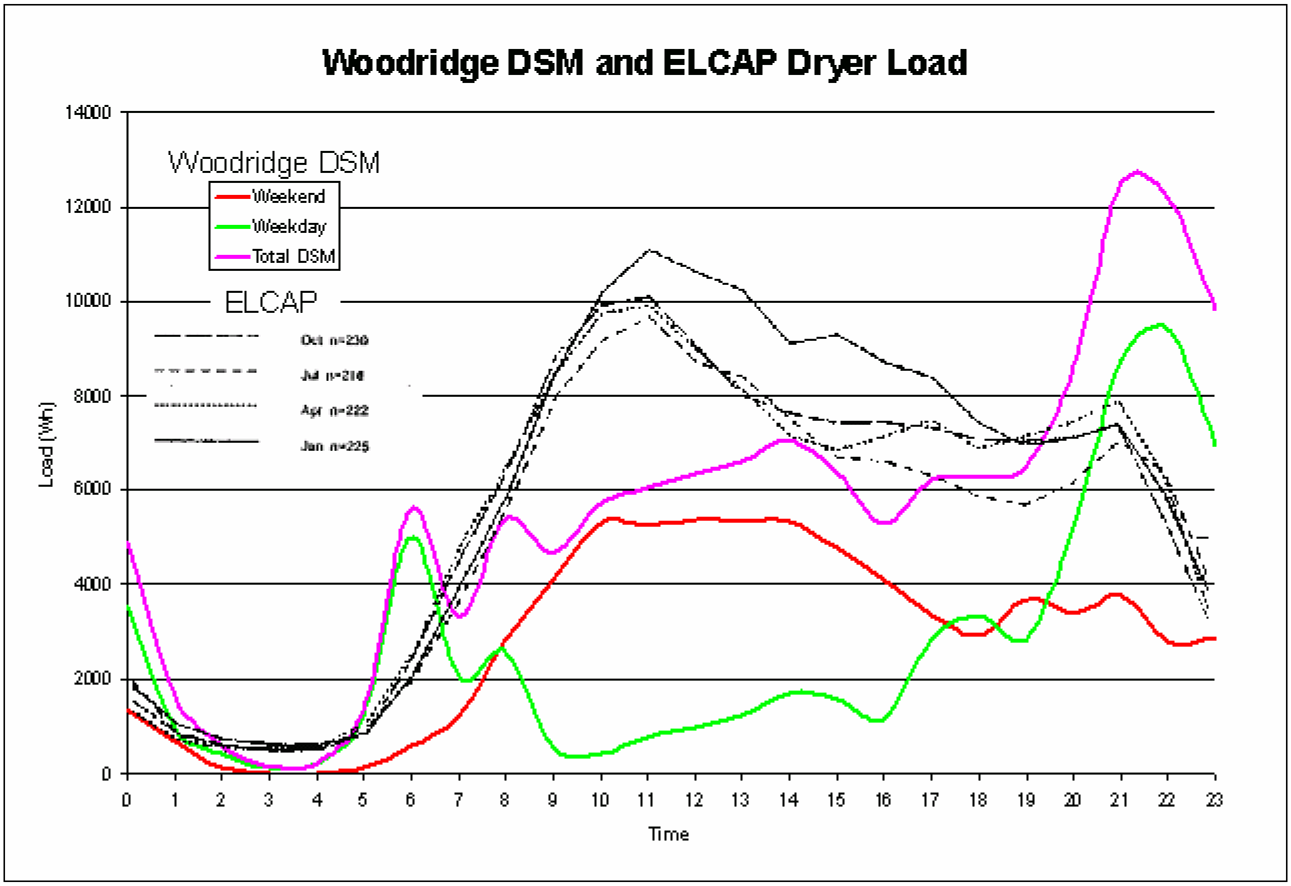
Comparison with ELCAP

The graph below (Graph #117) is offered as a comparison with dryer data found in the ELCAP[1] study. The daily dryer usage of the DSM dryers follows a significantly different load curve, showing a shift to early morning and late evening. One could offer a valid argument that there are three factors that could be responsible for the differences:

1. The Whirlpool Woodridge study that offered consumers a convenient way to shift when they use energy. The energy monitor and consumer education factors addressed in the Woodridge study also affect the times consumers choose to use their appliances.
2. Consumer lifestyles may have shifted between the late 1980s and 2005.
3. There may be regional differences between the Pacific NW and the upper Midwest.

Although the data may be somewhat inconclusive from the scientific perspective, the fact that the composite graph below shows a rise both before 7:00am and at 9:00pm seems to support the fact that these consumers made specific choices to shift dryer usage outside the TOU on-peak time of day. This is particularly noticeable on the weekday curve shown in the green line.

Regarding #2 and #3 above, recent studies don't show a large difference from the ELCAP study and regional differences don't seem to be apparent to a significiant degree. Note however, that time and regional comparisons are beyond the sope of this report.



Graph 117

Woodridge participants closing interview summary:

The closing interview was conducted at the consumer's homes at the close of the project pilot. Both heads of the household were present. Answers documented below are color-coded for the participants.

Energy & The Energy Monitoring System survey responses:

1. Describe how energy is used in your home? (E.g. Where does most of the energy cost go? Have you attempted to manage energy costs? If so, how?)
   - Most energy goes toward cooking, lights, hot water heater, AC, and laundry
   - Decided to set and leave the thermostat alone. However, may change the setting seasonally. Previously tried to change often or use programmable features but didn't like that approach.
   - Dryer and basement lights, halogen outdoor lights, freezer
   - Helped explain to kids and guests how they manage their electric bill.
   - Try to keep lights at a minimum
   - Cooking is considered primary energy use in home
   - Have tried to take advantage of TOU

2. What was your first impression of the EMS? Who pays the most attention to the EMS in your household?

- Tends to like gadgets in general. Used it more at first. First several months they looked at everything. Usage was similar between him and her. Once the novelty wore off they didn't look at the energy monitor as often.
- It was a good educational process.
- Liked ability to see where the energy dollars go.
- Learned how the home uses energy and made adjustments where appropriate.
- Went around house trying everything to see what it uses.
- Didn't want it on the counter because of its size.
- Everyone asks about it "What is it?"
- They watched it carefully to learn where the power is going.
- Once habits learned and family behavior was consistent, he doesn't look at it as much.
- He tended to look at watts, but she would have rather looked at dollars screens.
- Changed some bulbs to more efficient CF e.g. For example, outside lights that are left on all night.

3. How did the monitor affect your energy consumption habits? (Optional follow-on ... How much money to you feel you have saved on your electric costs that you would attribute to the energy monitor? What did you learn?)
    - Makes you much more aware.
    - Although it was a new home and therefore didn't have a baseline, they have adjusted their lifestyle to where these lifestyle changes have become standard practice.
    - Compared room-to-room.
    - Changed consumption habits, especially laundry habits.
    - The EMS was installed into a new home so there was no comparison with old consumption. They learned where to scale back on cost if necessary having learned the higher consumption components of the home.

4. What would you expect to pay for a system like the EMS?
    - Feel the cost should be in the $500 range, perhaps up to $1,000.
    - A 5-year payback on consumer investment for this type of device would be desirable.
    - $1200 - $2000 depending on what you want. (based somewhat on the knowledge of cost of a laptop computer)
    - System should be part of a new home.
    - $500-700 dollars. Could be part of a new home building process. When the builder or electrician walked them through to select options, that is where is should be presented.
    - Would also like to see water and gas monitoring.

5. If you could access energy monitor data from your PC instead of the stand-alone monitor, would that be valuable? (Similar/more/less valuable)
    - My Own PC
    - It depends on where the PC is located in the home. Being where the data is visible is a key factor.
    - [Current stand-alone] Monitor is much handier [than running on the PC].
    - They always leave PC on, so that would be convenient for this family. (Note that the PC is currently located in the Kitchen / Dining room. Same room as the EMS)

6. If you had a whole home monitor (WHM) instead of the full color screen by circuit, how would you see its use and value differently with the more limited functionality?

- OK, a whole home monitor would have value. Although they liked the layout and use of color by circuit in the EMS. They would like a whole-home monitor to have a 1-day total to compare by day.
- Whole-home monitor can't pinpoint the cause of consumption. They like having the history hour by hour to equate consumption with when you did laundry etc. More energy history would be needed than what the whole home monitor can provide.
- WHM- would still be helpful to compare month to month and try to beat the previous month.
- Like the breakdown of the current EMS better than seeing just the whole home monitored.
- WHM would not have the value of breakdown of usage [by circuit / appliance].

7. If you could change anything about the energy monitor, what would it be?
   - Make it easy to read
   - No new features requested
   - Probably wouldn't change anything on the EMS system.
   - Likes the graphic comparison.
   - Kitchen is perfect location for the monitor.
   - Like the touch-screen. A link to the PC may be good for evaluation purposes.
   - A link to power utility so it would update rate automatically if needed.

8. Would you like to see a report of your energy consumption? (Further analyzed and charted data - just a Y/N question)
   - yes
   - yes
   - yes
   - yes

Time-of-Use:

9. Has the TOU rate structure affected your family's energy habits?
   - It was just a new habit to learn. It was not a problem, just a change of household habits. Made them aware of why they should do laundry at night and weekends.
   - Made us more aware of how we use our appliances and save energy.
   - It [the Whirlpool EMS] changed their habits.
   - They learned to conserve.
   - It conditioned the family to be aware and conserve.
   - Explained the EMS a number of times to friends and family who come to visit.
   - The comparison with last year is great.
   - They are spending less now on electric for a larger house now than before they moved here.
   - Takes guess work out of costs.
   - TOU drives when they run the "heavy" appliances. Since peak/off is big price difference they learned to manage according to these prices.

10. Do you feel the TOU rate concept is fair? Why? Or Why not?
    - Yes TOU is fair, especially considering the energy issues facing the country.
    - Yes we are going to stay with TOU rate structure plan. We use it now out of habit
    - Fair, especially since most people work and can manage the TOU.
    - Since lower cost is evening it is convenient.

- Well... [hesitation ...] it's better to know what is going on and able to control it. [general agreement although hesitant]

11. How would you feel if the TOU time and rate changed daily? (Hourly?) (Have you heard of real-time-pricing? What technology in your home would make RTP an acceptable energy billing process? .. similar follow-up probes if needed)
    - RTP would be chaotic, but if that is what it takes to manage energy wisely, then it would be OK. Education is the key to understanding the energy issues and why things need to be done differently.
    - That would seem crazy, would definitely want help coping with a RTP rate structure. Having the DSM button sync-up with the RTP changes. Opt in/out and override would be essential.
    - RTP With advance warning would be ok. But would much rather have fixed times as the daily fluctuation would be quite inconvenient.
    - With RTP they could still balance schedule to manage home schedule around the rates.

DSM Appliances:

12. Did you use the DSM feature of your appliances equally, or some more than others? (Probes if needed . .. did your use of the DSM features changes over time? How often did you use the DSM feature? Etc)
    - Likes the DSM features (the Green/Red button) and they used it often.
    - Used the DSM button on the clothes dryer the most often. This was because in looking at the EMS, the dryer uses the most energy.
    - Used DSM button on the clothes washer and dryer most often. Teenagers do dishes as part of their chores and discipline. Therefore, they didn't use the DSM button on the dishwasher as often.
    - Used the dishwasher DSM button but not the washer and dryer. Loaded dish and pressed button. Usually run [dishwasher] once a day.

13. What would you change about the DSM appliances? Why?
    - The green/red LEDs should be larger or brighter, especially on the dishwasher.
    - I would like a time delay button so we could set appliance time to run
    - DSM functionality is good the way it is. The RED stop GREEN go is as simple and as useful as it gets.
    - Like the button on the dish. RTP would need to sync the button with today's price automatically.

14. If your utility company were to require RTP would this change your response to the value of these features? (Assume the appliance could respond to the daily/hourly pricing changes.)
    - Would want the red/green button type features to help manage.
    - I want to be able to control what happens or select automatic
    - Need advance warning notice. Difficult to manage and budget
    - Value per appliance should show a payback [of cost of the additional DSM feature] in one season (year?)

General discussion:

15. Can you summarize your experience with this energy pilot in a sentence or two?
    - Great education. It helped them learn to avoid excess consumption as a habit.

- It was an education. We learned how to control energy use. You learn it and then change your pattern
- It is important to make efficient (save energy) but retain consumer convenience.
- We were not previously aware of any of the energy saving options. Great educational experience on how to save energy.
- Excellent learning experience to learn how to manage cost and become aware.

16. What do you think of a company like Whirlpool doing this type of energy project and related research?
    - Whirlpool should be in this space. They are in a good position to do this type of thing.
    - A good thing for Whirlpool to look into.
    - Whirlpool - as a leading company, should be energy -conscious and energy-efficient.
    - I use energy to run all of my appliances. Nice to see Whirlpool working on energy.

Summary & conclusions of project learning:

Focusing on the key drivers for the Woodridge study, energy usage visibility and the load-shifting features of the DSM appliance set, there are two types of results.

1) Hard data:

Data provided by the monitoring system gave reasonable physical evidence of the success of the DSM appliance experiment. The pilot families changed their energy usage habits shifting peak use and saving money on their energy bills.

2) Soft Conclusions:

Soft conclusions could be arguable as they don't have the solid physical data. Yet some valid conclusions could likely be drawn by the combination of the hard data, the consumer interviews, and what we know about the homes and the demographics. For example, why was energy shifted off peak? What role did the energy monitor play as compared to the DSM appliance features? How much was driven by cost as compared with an educated consumer desiring to do what is right for the environment? What amount of lifestyle changes are deemed acceptable by the consumers?

As noted earlier in this document, the data generated by the Woodridge Study was not intended to be considered statistically valid for industry load curve analysis. However the many load curves presented tend to illustrate the impact of consumer lifestyles on energy consumption in the measured homes. Beyond the statistical limitation mentioned, the author and project manager presents the following observations:

1. Data supports the hypothesis that having convenient tools to help consumers shift and conserve energy can result in load shifting and energy cost savings.
2. Consumer acceptance of peak load shifting is enhanced by tools such as the DSM appliances.
3. Consumers who understand energy conservation and time-of-use issues can assist in achieving the desired results driven by changes in their lifestyles.
4. The load curves illustrated provide an interesting comparison with other similar studies. Although the sample size is small, similar patterns can be found that are quite consistent.

5. This data provides a regional comparison with other geographic areas.
6. Consumer surveys give a glimpse to the affect of easy access to a home dashboard that provides immediate feedback for energy consumption.

The author / project manager & special thanks:

At the Whirlpool Corporation Research & Engineering Center, Gale Horst is a Project Manager and Lead Engineer in Corporate Innovation Technology. In this role, he has studied various energy management concepts in the utility industry, participated in U.S. DOE discussion groups, and delivered a number of working concept prototypes and pilots. The mission of his work is to identify where Whirlpool technologies can deliver energy management solutions through advanced engineering and electronic technology.

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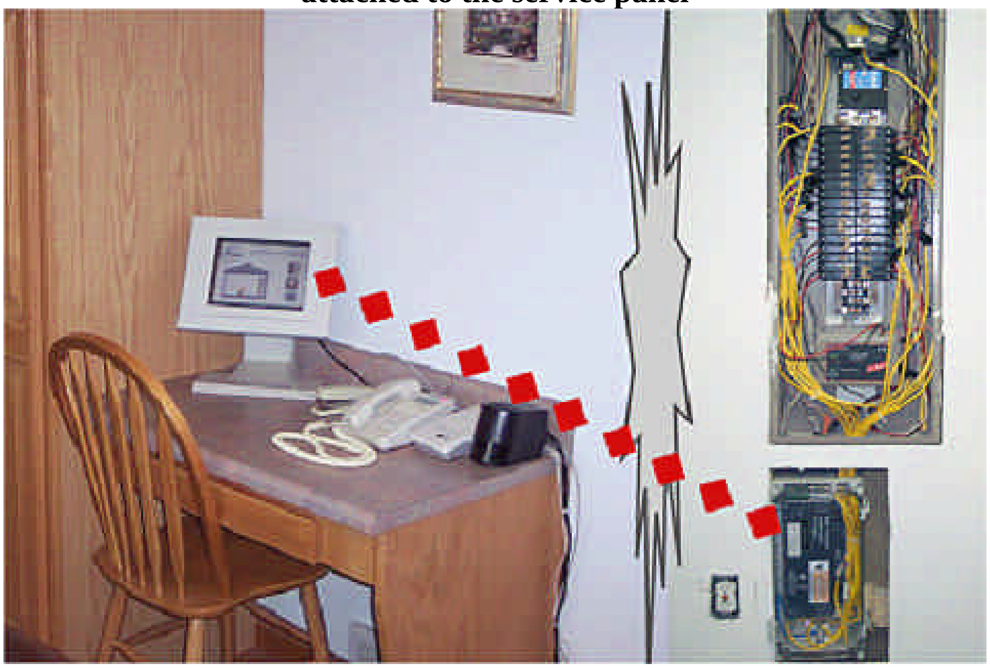
- Kristin Scovic - summer intern who participated in editing and proofreading
- The families who participated in the Woodridge study.

Appendix A: The installed components

Touch-screen monitor communicates with the energy logger attached to the service panel



There are a variety of residential service panels available from various vendors. The energy monitor can be fit or retro-fit into any panel. However, layout of the circuit breakers will enable more meaningful division of information on the monitor graphs.

Current sensors, service panel, data logger, installations

Background:

The notes below provide an overview of the components used in the Energy Monitoring System.

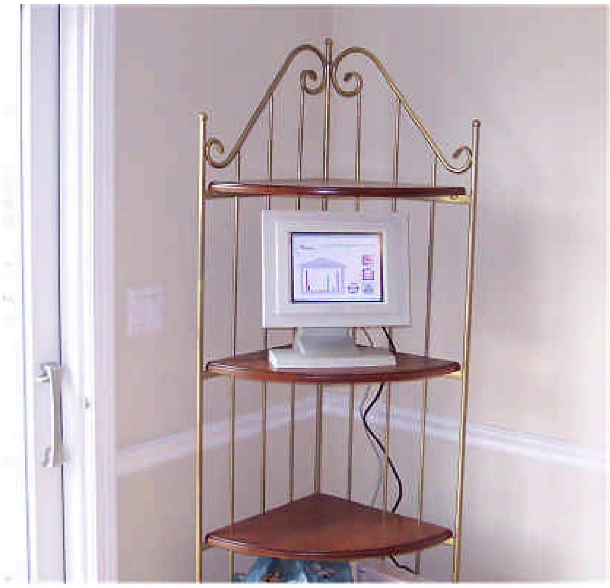
Components:

Eaton/Cutler-Hammer IQ Energy Sentry II data logger is a microprocessor driven device that logs data from up to 16 circuits (channels). For each channel (circuit) to be measured, a current sensor is utilized. The IQ Energy Sentry II measures and records calculated values, allowing users to track energy usage patterns of various metered points throughout the electrical distribution system. The IQ Energy Sentry II is capable of measuring the energy values of individual loads or processes. A selection of Current Sensors are utilized in current capacities (50 A, 70 A, 125 A, 200 A) that are attached to the IQ Energy Sentry II unit.

The information is reported to the consumer touch-screen monitor via a CAT5 cable using the Cutler-Hammer INCOM™ network protocol. The CAT5 cable runs between the Sentry II and the location of the touch-screen monitor. A serial converter converts the INCOM protocol to a serial protocol utilized by the consumer interface touch-screen. The photo at the left shows the CAT5 cable jack and the INCOM converter which converts the signal to RS-232 where the data interfaces with the touchscreen computer.

The touch-screen monitor is installed in a high-traffic area of the home. This graphical user interface allows the consumer to access energy consumption data both in real-time and historical format. The photos below show examples of completed installations of the energy monitoring system components.

Installed Energy Monitors

Installed service panel examples

Below are several electric service panels with energy monitoring system hardware attached.

Siemens Panel Eaton Cutler-Hammer Panel

Energy monitoring in the service panel:

Each electrician tends to lay out a home differently as far as what is on each circuit. Often several rooms have outlets on the same sockets. Although for major appliances, each is on a separate circuit making comparison graphs possible for these items.

References & footnotes

[1] **ELCAP -** End-Use Load and Consumer Assessment Program was conducted between 1986 and 1992 in the Pacific Northwest. The Office of Energy Resources of the Bonneville Power Administration P.O. Box 3621, Portland, OR 97208 (http://www.bpa.gov) conducted this study. The objective of ELCAP was to collect detailed, reliable end-use data on how electricity is used in Pacific Northwest homes and businesses. This report has served as a "source book" of end-use electricity consumption data for single-family residences for a variety of analytical and planning activities in demand-side management, forecasting, and energy conservation.

[2] **Parker - Danny Parker -** Parker, D. S., "Research Highlights from a Large Scale Residential Monitoring Study in a Hot Climate." http://www.fsec.ucf.edu/bldg/pubs/pf369/index.htm. Danny Parker is a Principal Research Scientist at the Florida Solar Energy Center (FSEC). A load research project by a large utility has monitored 204 residences in Central Florida, collecting detailed electricity end-use load data. In each home, 15-minute electric demand data is obtained on total electric power, space heating, cooling, water heating, dryers, cooking and pool energy use. Interior and exterior temperatures were also recorded. This is similar to other detailed end-use data monitored in the U.S. Pacific Northwest in the ELCAP project (Pratt et al., 1989) and the PG&E Appliance Metering Project (Brodsky and McNicoll, 1987). However, these data are of a more recent vintage and from a cooling dominated climate.

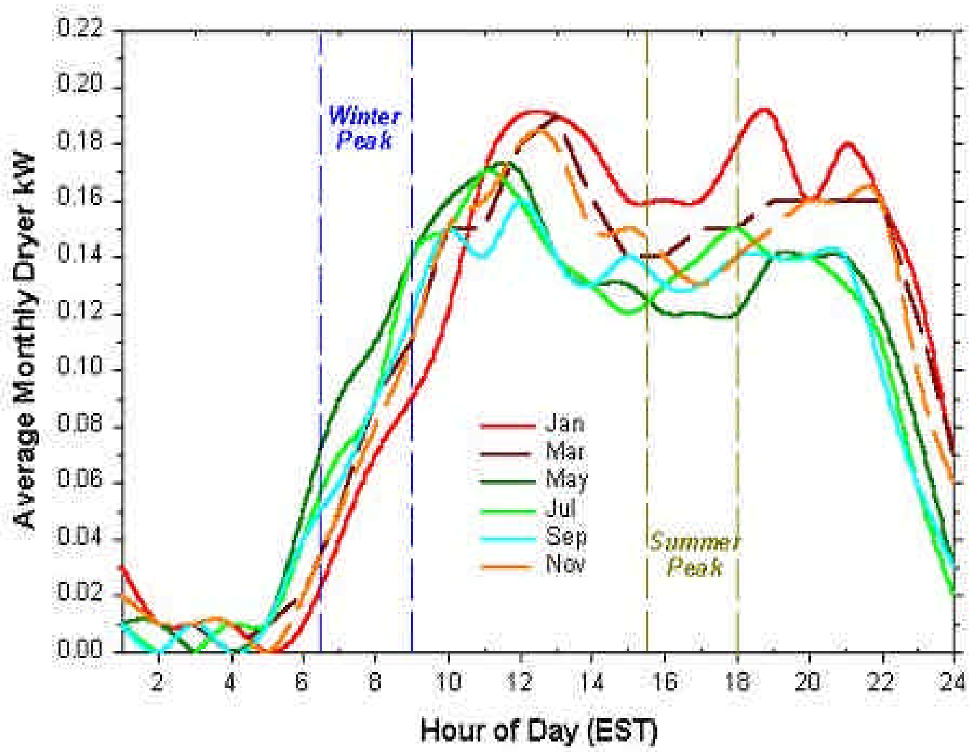


Figure 19. Monthly demand profile for clothes dryer.

